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AUTHOR Chaney, Bradford; And Others
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ABSTRACT

A survey instrument was sent to all doctorate-granting institutions and all institutions identified as offering doctorates in plant biology. Doctorate-granting institutions were identified using the U.S. Department of Education's Higher Education General Information Surveys (HEGIS) listings. Responses were received from plant biology program representatives at 197 of 198 institutions (99 percent). A total of 154 institutions were identified as offering graduate training in plant biology. Questions that were included in the 1983 and 1989 questionnaires concerned these issues: (1) the number of full-time faculty, postdoctoral fellows/associates, Ph.D. recipients, and full-time graduate students in plant biology; (2) the departments involved in providing graduate instruction in plant biology and the number of plant biology faculty in each department; (3) the number of foreign graduate students and postdoctorates in plant biology; (4) the three major disciplines within plant biology for graduate student training, postdoctoral research and training, and faculty research; (5) faculty vacancies in plant biology; (6) disciplines with surpluses or shortages of positions in various employment categories; (7) the major sources of financial support for graduate students and postdoctorates; and (8) the amount and sources of outside funding for plant biology research. A new question was added in 1989 that asked what factors are limiting progress in plant biology. Also, new data were collected on faculty with bachelor's degrees from foreign institutions, and financial data separating Hatch funds from other outside sources of funds. Unless stated otherwise, all statistics presented in this report are results from the 1983 and 1989 surveys. In general, statistics in this report are presented both as overall totals and using four major categories: institutional control (public/private), research size (based on federally financed research and development expenditures in the life science), number of full-time plant biology faculty (based on responses to the questionnaires), and geographic region (Northeast, Central, Southeast, West). More detailed discussion of the research methodology and a copy of the 1989 survey questionnaire are included in Appendixes B and C respectively. (KR)

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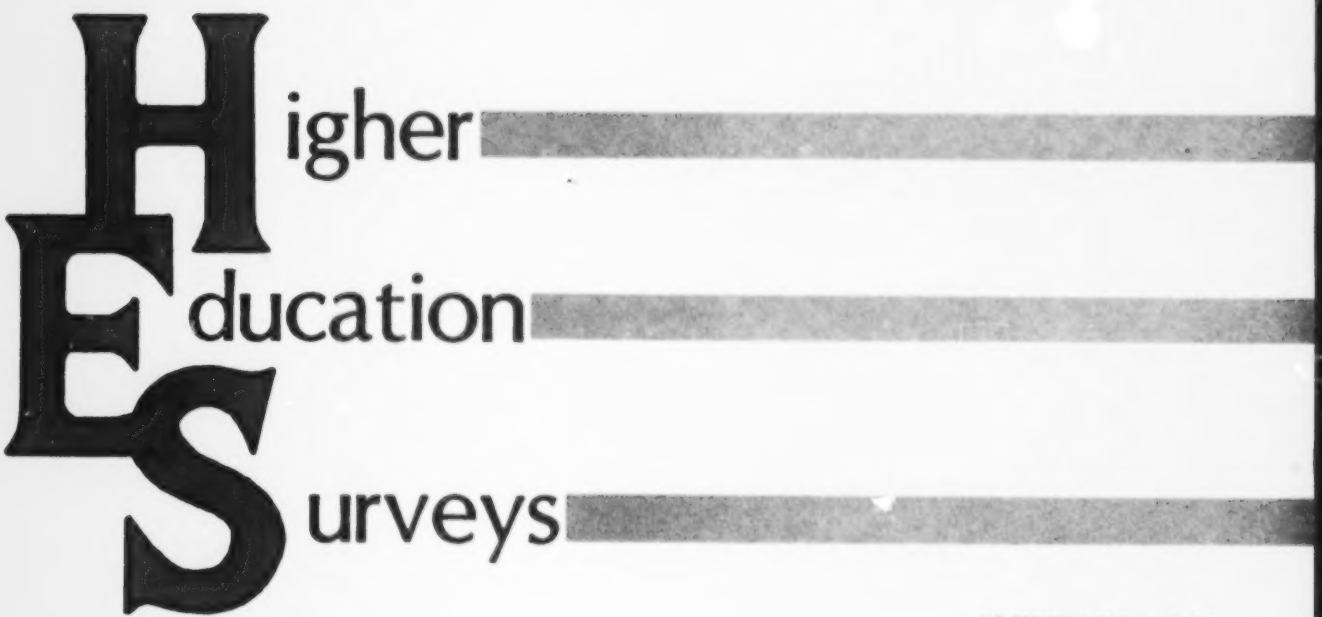

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Higher Education Survey Report
Survey Number 13
December 1990

A Survey System Sponsored by the National Science Foundation, the National Endowment for the Humanities, and the U.S. Department of Education

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PLANT BIOLOGY PERSONNEL AND TRAINING AT DOCTORATE-GRANTING INSTITUTIONS

Sponsored by and written for:

The National Science Foundation
Directorate for Biological, Behavioral and
Social Sciences

Prepared by:

Bradford Chaney, Survey Manager, Westat, Inc.
Elizabeth Farris, Project Director, Westat, Inc.
Patricia White, Senior Science Resources Analyst, NSF

Higher Education Surveys Report
Survey Number 13
December 1990

A survey system sponsored by the National Science Foundation, the National Endowment for the Humanities, and the U.S. Department of Education

Highlights

A spring 1989 HES survey was conducted of plant biology personnel and training at all U.S. institutions identified as offering doctorate degrees in Plant Biology. These results were compared to the findings of a similar study done in 1983.

- A total of 154 responding institutions were identified as offering graduate training in plant biology. The majority of these (89) were land-grant institutions, while the remainder included 25 public institutions and 40 private institutions.

- The departments in which plant biology faculty were most commonly located were, in order of frequency, agronomy and soil science, botany, biology, plant pathology, and horticulture.

- Several changes have occurred between 1982-83 and 1988-89 in the number of full-time faculty, postdoctoral fellows/associates, Ph.D. recipients, and full-time students in plant biology.

  - There were 4,517 full-time faculty in plant biology in 1988-89. This represents a decline of 2 percent from 1982-83. An increase back to the 1982-83 level (i.e., to 4,611) was projected for 1989-90.

  - The number of postdoctoral fellows and associates in plant biology increased from 1,009 in 1982-83 to 1,120 in 1988-89, with little change projected for 1989-90.

  - Graduate students in plant biology decreased 9 percent, from 8,023 in 1982-83 to 7,317 in 1988-89. However, an increase to 7,484 was projected for 1989-90. The number of graduate students who were U.S. citizens declined by 25 percent, while the number from foreign countries increased 55 percent.

  - The number of Ph.D. recipients declined 22 percent, from 925 in 1982-83 to 724 in 1988-89. An increase to 859 was projected for 1989-90.

- The percentage of females increased at least marginally in three of the four categories. The changes from 1982-83 to 1988-89 were from 7 percent to 10 percent among full-time faculty, from 21 percent to 27 percent among Ph.D. recipients, and from 31 percent to 33 percent among graduate students; there was no change at 29 percent among postdoctoral fellows.

- The percentage of plant biologists belonging to minority racial and ethnic groups has also increased for every category but full-time faculty. Among graduate students who were U.S. citizens, the proportion of minority students increased from 7 percent to 13 percent.

- The prominence (measured by the number of people involved) of molecular biology within plant biology has increased greatly: plant biology program representatives from 20 institutions listed it among the top three disciplines for faculty research in 1982-83, compared with those from 60 institutions in 1988-89. The three other largest fields--ecology, plant physiology, and systematics--were all mentioned less frequently than in 1982-83.

- The number of vacancies specifically in plant biology has increased from 213 in 1982-83 to 276 in 1988-89. The two areas in which plant biology program representatives expressed the greatest need to fill vacancies were molecular biology and plant physiology.

- Disciplines most frequently selected by plant biology program representatives as having more positions to fill than people trained to fill them were molecular biology and biochemistry. Disciplines frequently listed as primarily having a shortage of positions were systematics, anatomy/morphology, and evolution.

- Outside financial support for plant biology research has been relatively stable when compared to the rate of inflation. Of a total $242 million in 1988-89, federal support accounted for 49 percent of funds and state support for 34 percent. Hatch funds (authorized through the Hatch Act of 1887 to establish agricultural experiment stations to conduct agricultural research) accounted for one-third of all outside funding for plant biology research. Representatives of many institutions expressed difficulty in identifying all outside funding for plant biology research, however, so $242 million is an underestimate of the total amount of financial support. The total estimated outside funding for all of the life sciences in 1988 was $6 billion.

- The major sources of funding for graduate students and postdoctoral fellows and associates have remained stable. Graduate students were most commonly supported through institutional support (28 percent) and federal research grants (21 percent), and postdoctoral fellows and associates by federal research grants (52 percent).

- The major factors program representatives saw as limiting their institution's progress in plant biology were insufficient financial support for research (86 percent) and insufficient financial support for graduate students (83 percent).

Acknowledgments

This survey on Plant Biology Personnel and Training was conducted by Westat, Inc., at the request of the National Science Foundation's Directorate for Biological, Behavioral, and Social Sciences, and under the direction of the Division of Science Resources Studies of the National Science Foundation. The following persons guided the development of the study and provided technical review of the study and report:

- Mary Clutter, Assistant Director, Directorate for Biological, Behavioral, and Social Sciences, National Science Foundation
- Patricia White, HES Program Officer, Education and Human Resources Program, Division of Science Resources Studies, National Science Foundation
- Mary Golladay, Director, Education and Human Resources Program, Division of Science Resources Studies, National Science Foundation

Other individuals who contributed to the data collection process or the presentation of survey results include the following:

- Sonia Malinoff, Budget and Operations Officer, Directorate of Biological, Behavioral, and Social Sciences, National Science Foundation
- Melvin Josephs, Executive Director, American Society of Plant Physiologists
- Machi Dilworth, Director, Special Projects Program, Division of Instrumentation and Resources, National Science Foundation

From Westat, Debbie Alexander was the data preparation supervisor for the survey, and Sheila Heaviside supervised the telephone followup.

We also acknowledge the indispensable contribution of the many officials, faculty, and staff members at the sampled institutions who completed the survey questionnaires. Some individuals devoted considerable effort to coordinating responses among many separate departments involved in plant biology, and their work was critical to the success of this survey.

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Background

Plant biology has a critical role in helping this nation and the world make the agricultural advances needed in preparing for the 21st century. In 1983, the National Academy of Sciences' Briefing Panel on Agricultural Research Opportunities identified plant biology specifically as a research area that is "likely to return the highest scientific dividends as a result of incremental federal investments." Responding to this need, in 1984 the National Science Foundation (NSF) chose to make plant biology an area of emphasis and initiated new funding programs. Other new funding programs have also been initiated by the U.S. Department of Energy and the U.S. Department of Agriculture.

Information available on plant biology is limited, especially for subfields within plant biology, due to the tendency of researchers to collect data for much larger groupings (i.e., all of the life sciences). To collect information specifically on plant biology training and personnel, a survey was conducted in 1983 for NSF's Division of Physiology, Cellular and Molecular Biology. The results were published in the report Plant Biology Personnel and Training at Doctorate-granting Institutions (November 1984). NSF has stated that report had a major impact on planning at NSF and other agencies, as well as on the Congress.

To update information from the 1983 study, a second survey was mailed in April 1989. The survey was modeled on the 1983 questionnaire to enhance the ability to identify trends over the entire period. Questions that were included on both questionnaires concerned these issues:

- the number of full-time faculty, postdoctoral fellows/associates, Ph.D. recipients, and full-time graduate students in plant biology;
- the departments involved in providing graduate instruction in plant biology and the number of plant biology faculty in each department;
- the number of foreign graduate students and postdoctorates in plant biology;
- the three major disciplines within plant biology for graduate student training, postdoctoral research and training, and faculty research;
- faculty vacancies in plant biology;
- disciplines with surpluses or shortages of positions in various employment categories;
- the major sources of financial support for graduate students and postdoctorates; and

- the amount and sources of outside funding for plant biology research.

A new question was added in 1989 that asked what factors are limiting progress in plant biology. Also, new data were collected on faculty with bachelor's degrees from foreign institutions, and financial data separating Hatch funds from other outside sources of funds.[1]

The survey covered the universe of departments offering doctorate work in plant biology. Thus, it was sent to all doctorate-granting institutions and all institutions identified as offering doctorates in plant biology. Doctorate-granting institutions were identified using the U.S. Department of Education's Higher Education General Information Surveys (HEGIS) listing (see page B-3 for definition). Plant biology program representatives were identified and institutions with plant biology graduate training in more than one department were asked to designate a coordinator who would be responsible for compiling numeric data and opinions from all plant biology departments and providing a single response for the institution. Responses were received from plant biology program representatives at 197 of 198 institutions (99 percent). A total of 155 institutions were identified as offering graduate training in plant biology. Given the high response rate, no weighting for non-response was performed. In this report, statistics are presented as representing the entire population of plant biology programs, because of the known small size of the plant biology program at the institution omitted. Unless stated otherwise, all statistics presented in this report are results from the 1983 and 1989 surveys. More detailed discussion of the research methodology and a copy of the 1989 survey questionnaire are included in Appendixes B and C respectively.

In general, statistics in this report are presented both as overall totals and using four major categories: institutional control (public/private), research size (based on federally financed research and development expenditures in the life sciences), number of full-time plant biology faculty (based on responses to the questionnaires), and geographic region (Northeast, Central, Southeast, West).

The two "research-size" categories used are the top 20 institutions with the largest federally financed R&D expenditures in the life sciences in fiscal year 1988, and those not in the top 20. For analysis, institutions were divided into those with full-time plant biology faculty numbering 1-5, 6-25, and 26 or more. These were used to indicate small, medium and large plant biology programs.

[1]The Hatch Act of 1887 authorized funds to establish agricultural experiment stations to conduct agricultural research. These funds are used to provide funds on a matching basis for agricultural experimental stations, and they are a major part of funding for plant biology research.

Land-grant institutions are listed separately within the public and private categories. Land-grant institutions originated through the First Morrill Act of 1862, which authorized public land grants to states for the establishment and maintenance of agricultural and mechanical colleges. Since that time, land-grant institutions have become a primary source of agricultural research. The Hatch Act of 1887 further established agricultural experiment stations to conduct agricultural research, and was used to greatly develop agricultural research at land-grant institutions.[2]

Where Plant Biology is Taught

Of the 154 responses received from institutions identified as training graduate students in plant biology, 89 (58 percent) were from plant biology departmental representatives at public land-grant institutions, 24 were from public institutions that were not land-grant institutions, and 41 were from private institutions (Appendix Table A-1). Plant biology programs varied greatly in size. At 60 institutions, the number of plant biology faculty reported for each institution was between 6 and 25, while 47 institutions reported 5 or fewer plant biology faculty, and 47 had 26 or more. Plant biology programs were more commonly located in the Central and Southeast regions than in the Northeast or the West.

Division Within Institution

Among all institutions (in 1988-89), the administrative unit that was the primary focus for training graduate students in plant biology was the Division (or College) of Arts and Sciences (62 percent; Figure 1; Appendix Table A-1). In 1982-83, most plant biology training (54 percent; Appendix Table A-2) was also offered in Arts and Sciences, but to a lesser degree than in 1988-89. In 1988-89, the 20 largest institutions had a greater percentage (80 percent) placing their primary focus within the Arts and Sciences than the 62 percent overall.[3] However, the larger *programs* tended to focus their efforts

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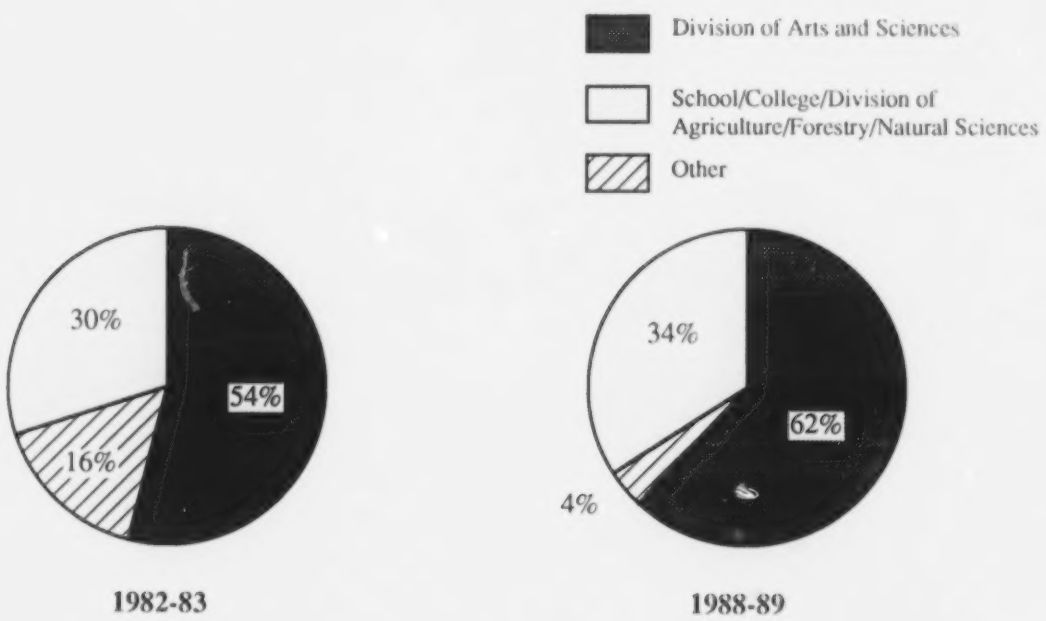
[2] In one case, a land-grant institution has both public and private components. In this report, the institution is counted as private when making public/private distinctions, but also as a land-grant institution. Because of this case that straddles the public/private categories, the totals presented for land-grant institutions do not strictly represent a subset of the totals for public institutions.

[3] The 20 largest institutions are defined as the largest 20 institutions with graduate programs in plant biology based on the amount of federally financed research and development expenditures in 1988. Published in **Academic Science/Engineering R&D Funds: Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of the 50 largest such institutions.

Figure 1. Major administrative unit that is the primary focus for training graduate students in plant biology, academic years 1982-83 and 1988-89: United States



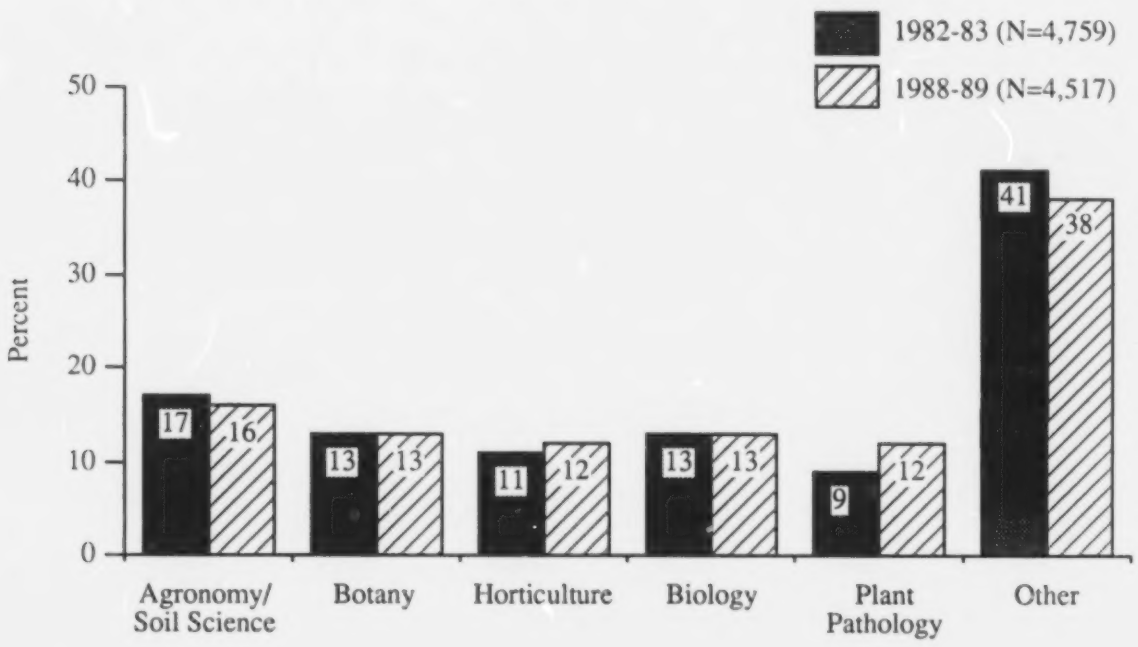
Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

within the more specialized School (or College or Division) of Agriculture, Forestry, or Natural Resources: this was true for 87 percent of institutions with the greatest number (26 or more) of plant biology faculty. Private institutions tended to have plant biology in the Arts and Sciences (85 percent), while public institutions were somewhat evenly split between the Arts and Sciences, and Agriculture, Forestry, or Natural Resources. Institutions in the West were more likely to offer plant biology in Agriculture, Forestry, or Natural Resources (47 percent) than those in the Northeast (24 percent).

Types/Numbers of Departments

As noted previously, one institutional representative was asked to compile information from all departments involved in training graduate students in plant biology in 1988-89. For each department they collected the following on full-time plant biology faculty: the total number; the number training graduate students in 1988-89; and the number with bachelor's degrees from foreign institutions. Depending on the size of the plant biology program and the organizational structure of the institution, plant biology faculty were distributed among 1 to 13 departments per institution (Appendix Table A-3). These departments included some specifically devoted to plant science as well as others with a much more general focus (e.g., biology) or an overlapping focus (e.g., biochemistry). Of 4,517 total faculty in plant biology, 724 (16 percent) were in departments of agronomy and soil science, 589 (13 percent) in botany departments, 584 (13 percent) in biology, 562 (12 percent) in plant pathology, and 531 (12 percent) in horticulture (Figure 2). These are similar to findings for 1982-83.

Figure 2. Plant biology faculty by department, academic years 1982-83 and 1988-89: United States



Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

By far, in 1988-89 most plant biology faculty (4,237 of 4,517, or 94 percent) were at public institutions, with 3,671 (81 percent) at land-grant institutions (Appendix Table A-3). Comparable figures for 1982-83 were 4,491 of 4,759 plant biology faculty (94 percent) at public institutions, with 3,802 (80 percent) at land-grant institutions (Appendix Table A-4). These numbers were much greater than would be expected based on the number of institutions alone. (As noted earlier, public institutions in 1988-89 were 73 percent of all institutions offering graduate training in plant biology, and land-grant institutions were 58 percent.) Thus, public institutions and land-grant institutions had larger plant biology programs than other institutions. In 1988-89 there were 717 plant biology faculty (16 percent) at the 20 largest institutions as determined by federally financed R&D expenditures in the life sciences. In 1982-83, there were 863 plant biology faculty (17 percent) at the 20 largest institutions.

In the 1988-89 academic year, 79 percent of all plant biology faculty were engaged in training graduate students (Table 1). This percentage did not vary greatly between public and private institutions, or between the 20 largest and the remaining institutions. However, it did vary among the different departments. For example, 94 percent of plant biology faculty within botany departments were training graduate students in 1988-89, compared

Table 1. Percentage of plant biology faculty training graduate students by department, academic years 1982-83 and 1988-89: United States

Department	All institutions		Land-grant	
	1982-83	1988-89	1982-83	1988-89
Total	81	79	79	79
Botany	90	94	88	93
Plant science	72	87	72	87
Agronomy and soil science	73	76	74	76
Biology	83	83	81	81
Food sciences*	-	71	-	62
Horticulture	73	75	73	78
Plant pathology	82	77	82	79
Forestry	79	73	79	69
Plant and soil science	71	71	69	78

*Not a separate category in the 1984 report.

NOTE: Only those department names with totals of more than 150 plant biologists are listed.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table A, page 1.

with 83 percent of plant biology faculty in biology departments and 75 percent in horticulture.

Current Description of Plant Biology Personnel

Program representatives were asked to state the total number of plant biology full-time faculty, postdoctoral fellows, graduate students, and Ph.D. recipients in 1988-89, and the estimated number in 1989-90. For 1988-89, they were also asked to provide breakdowns by gender and minority racial/ethnic groups (e.g., American Indians/Alaskan Native, Asian or Pacific Islander, Black, and Hispanic).[4] For faculty, they were asked to give the number training graduate students, the number with bachelor's degrees from foreign institutions, and the number of those graduates of foreign institutions who were teaching undergraduates. For graduate students and postdoctorates, they were asked the number of male and female foreign students, and the number of those that were from developing countries. Comparable information on all of these items, except number with bachelor's degrees from foreign institutions, was collected in the 1983 survey.

Faculty

In 1988-89 there were 4,517 full-time plant biology faculty in departments offering graduate instruction in plant biology (Appendix Table A-5). For 1989-90, institutions predicted a slight (2 percent) increase in the number of faculty to 4,611. A 3 percent increase (from 4,237 to 4,344) was expected among the public institutions, while the private institutions expected a 5 percent decline (from 280 to 267).

In plant biology programs, 10 percent of all full-time faculty were female. This is a slight increase from 7 percent in 1982-83 (Figure 3; Appendix Table A-5). A somewhat higher percentage of faculty were female at private institutions (15 percent) than public institutions (10 percent), and at institutions with 5 or fewer faculty (16 percent) than at those with 26 or more faculty (9 percent). As with the distribution of faculty with bachelor's degrees from foreign institutions, the greatest number of women was at public institutions despite the somewhat greater percentage of female plant biology faculty at private institutions.

Racial and ethnic minorities (who were U.S. citizens) were 4 percent (in both 1988-89 and 1982-83) of all full-time faculty in plant biology programs. There was little variation among institutions based on research size, faculty size, or control in the percentage of faculty that were minorities.

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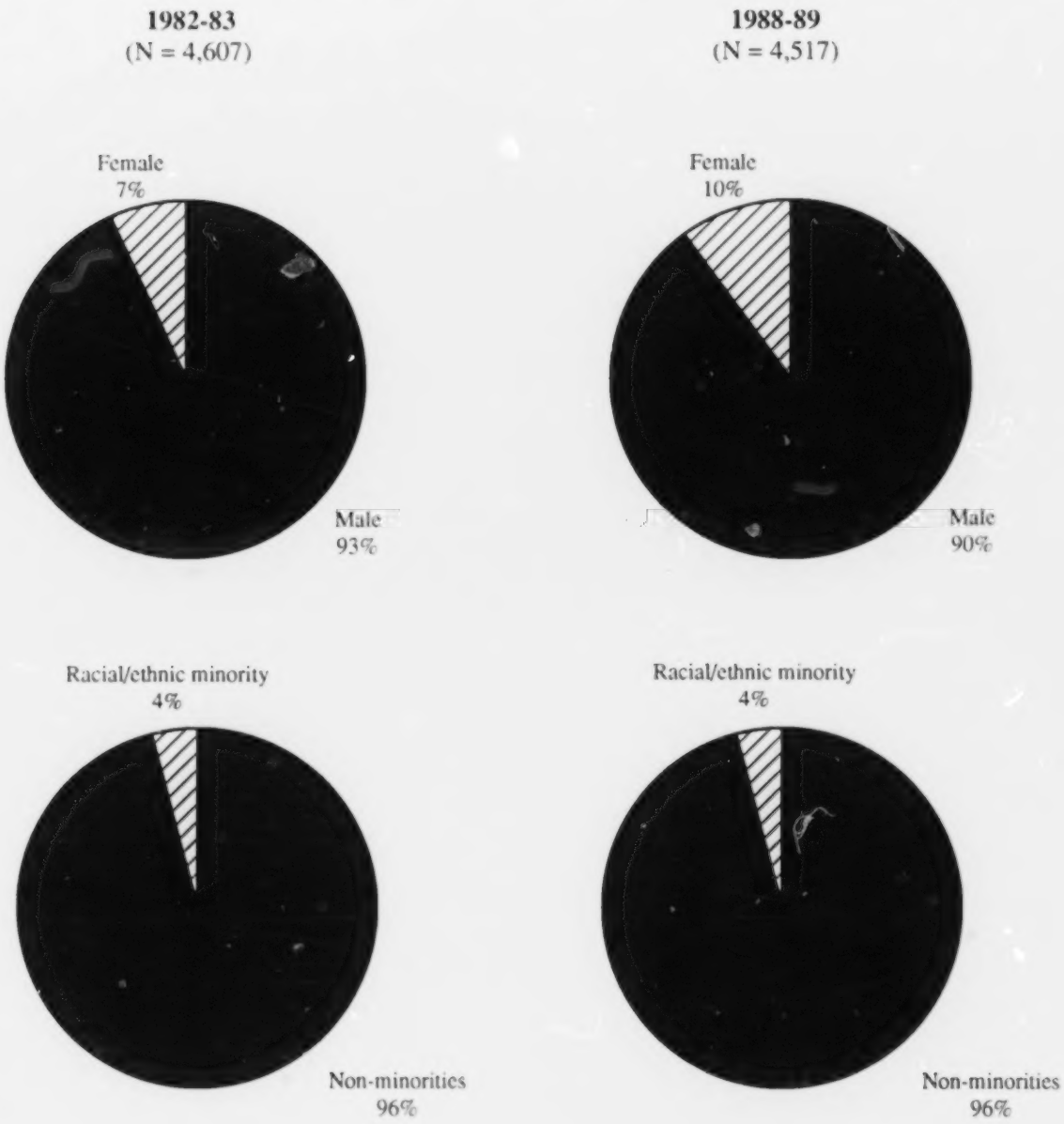
[4] Information on racial/ethnic minority status was not collected for all personnel, but only for those who were U.S. citizens. Information was collected on the number of graduate students and postdoctorates from foreign countries, so the percentage that were minorities for those groups can be calculated based on all graduate students and postdoctorates, or on those who were U.S. citizens. For faculty and Ph.D. recipients, however, no information was collected on the number who were U.S. citizens, so percentages are based on all plant biology faculty and Ph.D. recipients.

Figure 3. Full-time faculty in plant biology programs, academic years 1982-83 and 1988-89: United States



Note: Racial/ethnic minority figures represent the percentage of full-time faculty in plant biology programs that were racial/ethnic minorities (or non-minorities) and U.S. citizens.

Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

Most faculty (3,648 or 81 percent) were concentrated in those institutions with 26 or more faculty in plant biology. The largest number of faculty was in the Southeast (1,643, or 36 percent), while only 480 (11 percent) were in the Northeast (Appendix Table A-6).

As noted earlier, 79 percent of full-time plant biology faculty in 1988-89 were training graduate students. However, the percentage was lower in institutions with 26 or more faculty (78 percent) than in those with 25 or fewer faculty (82-85 percent), and in the West (78 percent) and Southeast (71 percent) than in the Northeast (85 percent) and Central (89 percent) regions (Appendix Table A-6).

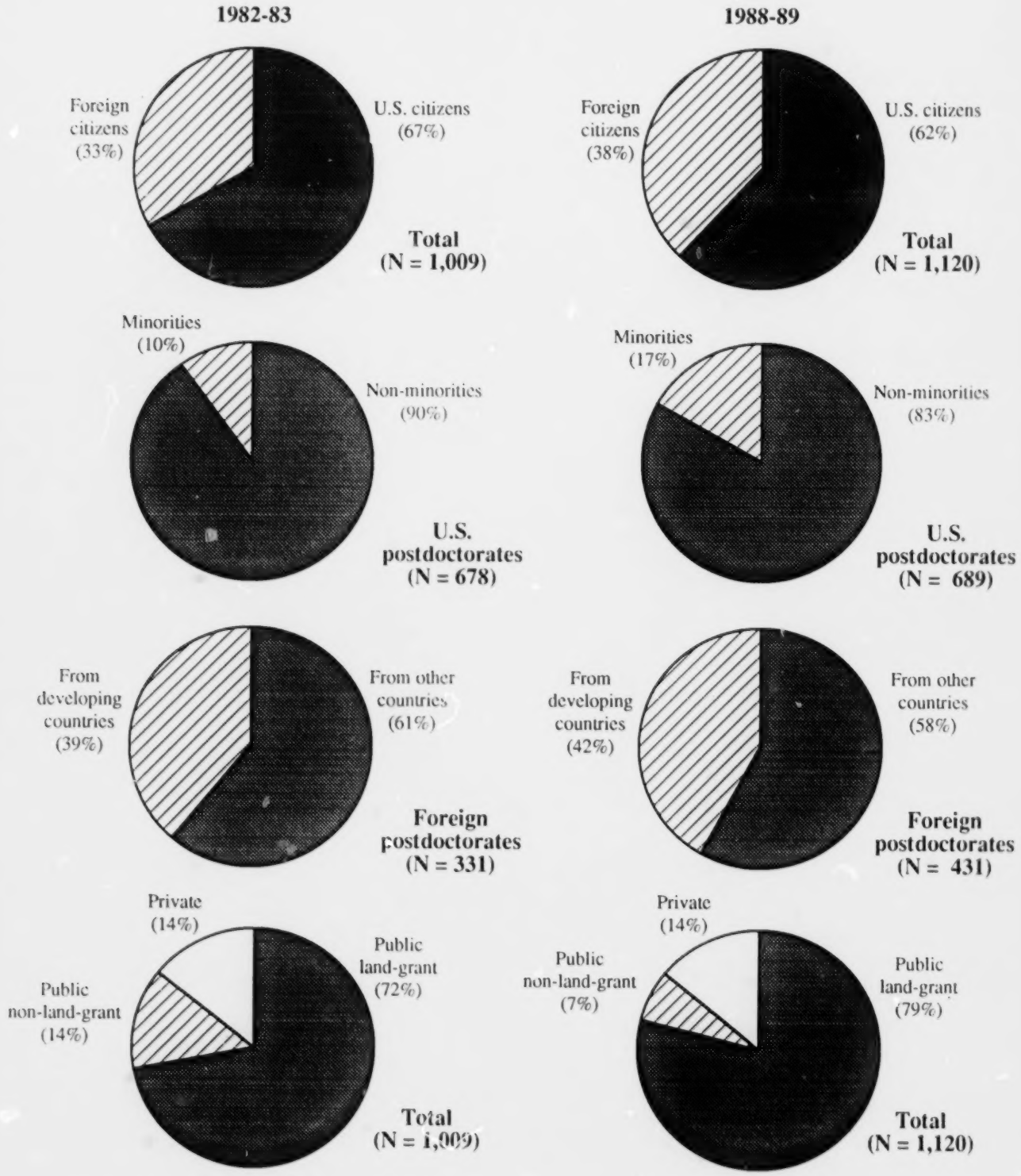
Of the full-time faculty in 1988-89, 7 percent had bachelor's degrees from foreign institutions; 5 percent both had bachelor's degrees from foreign institutions and were teaching undergraduates. Faculty with bachelor's degrees from foreign institutions formed a higher percentage at private institutions (16 percent) than at public institutions (7 percent), and at institutions with 5 or fewer faculty (17 percent) than at those with 26 or more faculty (6 percent; Appendix Table A-6). However, since private and small institutions had relatively few faculty, the actual number of faculty with bachelor's degrees from foreign institutions was smaller at those institutions despite the higher percentage rates.

Postdoctoral Fellows and Associates

In 1988-89, there were 1,120 postdoctoral fellows and associates in plant biology (Appendix Table A-7). This number was expected to remain relatively stable in 1989-90. Of these postdoctorates, 29 percent were female. This proportion is higher than that for full-time faculty (10 percent), and may suggest a future change in the proportion of women among the faculty as well (Table 2). In fact, the proportion of females among postdoctorates was moderately higher among U.S. citizens, who may be more likely to be faculty and researchers in the U.S. in the future. The study showed 34 percent of postdoctorates who were U.S. citizens were female, compared with 23 percent of those from foreign countries. These findings are similar to results of the 1982-83 study.

Racial and ethnic minorities comprised 11 percent of all postdoctorates and 17 percent of postdoctorates who were U.S. citizens, which was somewhat higher than the 4 percent found among faculty (Figure 4; Appendix Tables A-7 and A-8). Figures for 1982-83 show that 7 percent of all postdoctorates and 11 percent of those who were U.S. citizens were racial/ethnic minorities. Roughly two-fifths of postdoctoral fellows and associates were from foreign countries (30 percent were males, and 9 percent were females), with 16 percent of all postdoctorates from developing countries.

Figure 4. Postdoctoral fellows/associates in plant biology programs, academic years 1982-83 and 1988-89: United States



Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

Table 2. Percent distribution of postdoctorates/associates and full-time graduate students by citizenship and gender, academic years 1982-83 and 1988-89: United States

Citizenship	1982-83			1988-89		
	Total number	Percent male	Percent female	Total number	Percent male	Percent female
			Postdoctorates/associates			
Total	1,009	71	29	1,120	71	29
U.S. citizens	678	66	34	689	66	34
Foreign	331	80	20	431	77	23
			Full-time graduate students			
Total	8,023	69	31	7,317	67	33
U.S. citizens	6,411	66	34	4,826	63	37
Foreign	1,612	80	20	2,491	73	27

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions '(HES 13), National Science Foundation, 1990 (survey conducted in 1989), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 5, p. 18.

As with faculty, in 1988-89 the great majority of postdoctoral fellows and associates were at public institutions (964 of 1,120, or 86 percent), and especially at land-grant institutions (890, or 80 percent). Many of the postdoctorates were concentrated in the largest schools. The 20 largest institutions in federally financed research and development expenditures in the life sciences had 333 postdoctorates (30 percent), while institutions with 26 or more plant biology faculty had 776 (69 percent). Unlike the distribution of faculty (most were in the Southeast), postdoctoral fellows and associates were most often at institutions in the West (403, or 36 percent). The Northeast had the smallest number of postdoctorates (108, or 10 percent), as was the case with faculty.

In general, the proportions of postdoctorate fellows and associates in 1988-89 who were females, minorities, or foreign did not vary greatly from one category of institution to another, except for some regional variations. Females comprised only 23 percent of all postdoctorates in the Southeast, but 36 percent in the Northeast; and minorities formed 17 percent of postdoctorates in the Southeast, but 5 percent in the Central region and 7 percent in the Northeast. Foreign students were 47 percent of all postdoctorates in the Southeast, compared with 32 percent in the West; those

foreign students from developing countries were 23 percent of postdoctorates in the Southeast, but 11 percent in the Northeast and 12 percent in the West.

Graduate Students

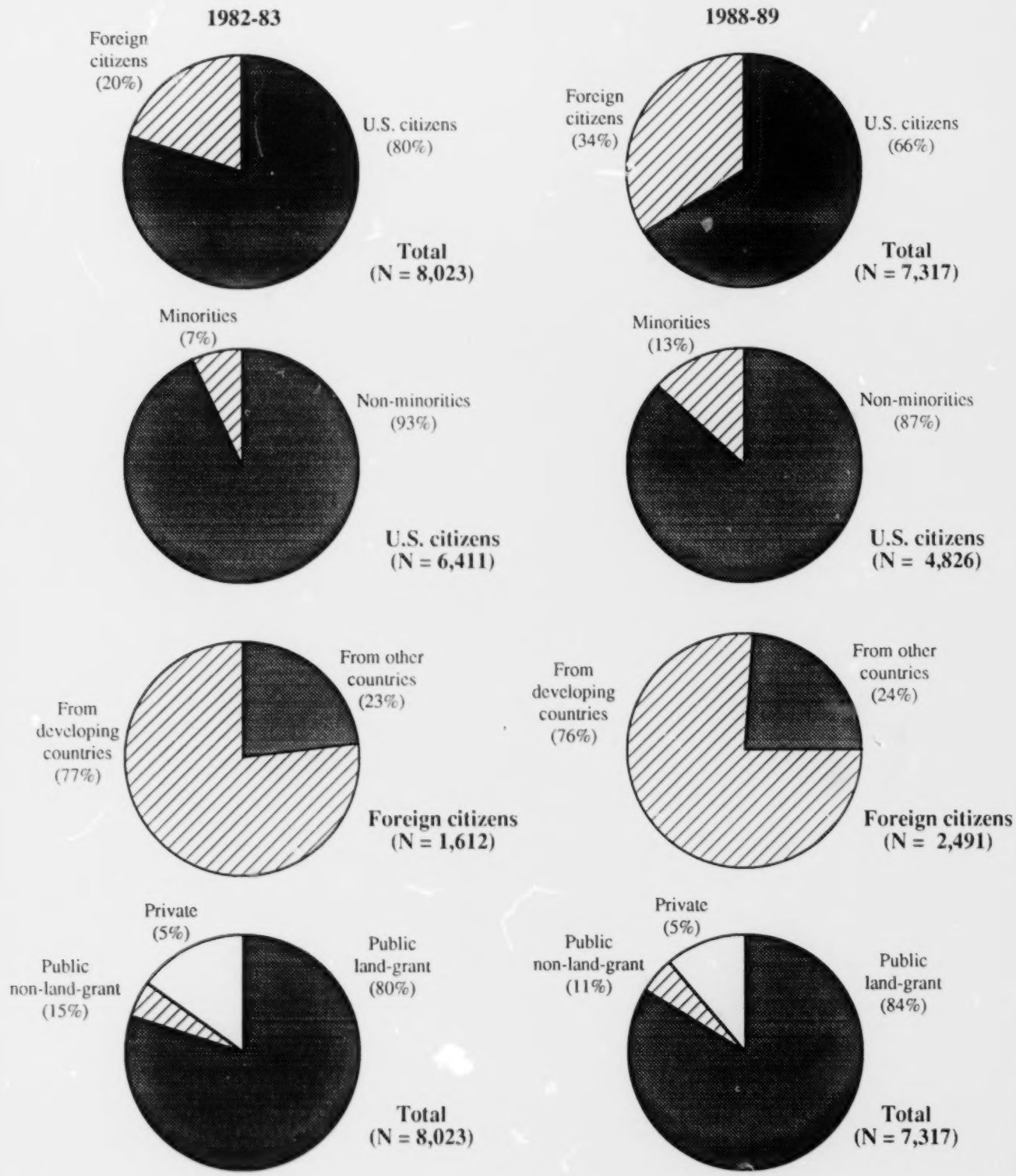
There were 7,317 full-time graduate students in plant biology in 1988-89, with a slight increase to 7,484 predicted for 1989-90 (Figure 5; Appendix Table A-9). This compares with 69,556 graduate students in all of the life sciences at doctorate-granting institutions.[5] The percentage of female graduate students in plant biology (33 percent) was similar to, but slightly higher than, the percentage of female postdoctorates (29 percent). This again suggests reasons to expect increases in the proportion of women in faculty positions in the future (from the current 10 percent). As with postdoctorates, the proportion of females among graduate students was higher among U.S. citizens than among foreign students: 37 percent were female, compared with 27 percent of foreign graduate students (Table 2). In 1982-83, females comprised 31 percent of all postdoctorates, 34 percent of U.S. citizen postdoctorates, and 20 percent of all foreign postdoctorates (Appendix Table A-10). Racial/ethnic minorities were 9 percent of all graduate students and 13 percent of the graduate students who were U.S. citizens. This is somewhat more than the 4 percent that were full-time faculty, but slightly less than the percentage found for postdoctorates. Foreign students were one-third of all graduate students (25 percent male and 9 percent female), with roughly three-fourths (26 percent of all graduate students) from developing countries. This percentage from developing countries was much higher than that found for postdoctorates; (16 percent of all postdoctorates, or 42 percent of those from foreign countries).

Graduate students were primarily located at public institutions (6,878 of 7,317, or 94 percent), and specifically at land-grant institutions (6,142, or 84 percent; Appendix Table A-9). One-fifth (1,326) of graduate students were at the 20 largest institutions in federally financed research and development expenditures in the life sciences, and four-fifths (5,881) at institutions with 26 faculty or more. Graduate students in plant biology were most often at institutions in the Southeast (2,455, or 34 percent), and least often in the Northeast (716, or 10 percent).

Some differences occurred among institutions in the make-up of graduate students in plant biology. A higher proportion of graduate students were female at private institutions (43 percent), institutions with 25 or fewer plant biology faculty (41 percent), and institutions in the Northeast (43 percent), than among institutions overall (33 percent). Male foreign students were more common at public institutions (26 percent) than private institutions (13 percent), at

[5] **Selected Data on Graduate Students and Postdoctorates in Sciences and Engineering, Fall 1988**. J.G. Huckenpahler, Division of Science Resources Studies, National Science Foundation, NSF 90-324, Table 15 (Washington, D.C., 1990). Life sciences includes biological and agricultural sciences, and health fields.

Figure 5. Graduate students in plant biology programs, academic years 1982-83 and 1988-89: United States



Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

institutions with 26 or more faculty (27 percent) than those with fewer than 26 faculty (16 percent at institutions with 1 to 5 plant biology faculty, and 14 percent at those with 6 to 25 faculty), and at institutions in the Southeast (28 percent) than those in the Northeast (17 percent). Similar patterns occurred for students from developing countries.

Ph.D. Recipients

In 1988-89, there were 724 Ph.D. recipients in plant biology, from a total of 5,123 Ph.D. recipients in all of the agricultural and biological sciences[6] (Appendix Table A-11). This number was expected to increase to 859 (a 19 percent increase) in 1989-90. Of the 1988-89 recipients, 27 percent were female and 10 percent racial/ethnic minorities. The 724 Ph.D. recipients in 1988-89 represent a 22 percent decline from the 925 Ph.D. recipients in 1982-83 (Appendix Table A-12).

In 1988-89, Ph.D. recipients were located largely in public institutions (653 of 724, or 90 percent), and land-grant institutions in particular (595, or 82 percent; Appendix Table A-11). One-fifth (142, or 19 percent) were at the 20 largest institutions based on federally financed research and development expenditures, and 582 (80 percent) were at institutions with 26 plant biology faculty or more. Two-thirds (457) were in either the Central or Southeast regions.

There was a somewhat higher percentage of females among Ph.D. recipients in plant biology in the Northeast (33 percent) than in the Southeast (23 percent). Minority groups were proportionally more highly represented in private institutions (28 percent) than public institutions (8 percent), in institutions with 25 or fewer plant biology faculty (15 to 21 percent) than in institutions with 26 or more (7 percent), and in the West (17 percent) than in other regions (ranging from 6 to 9 percent).

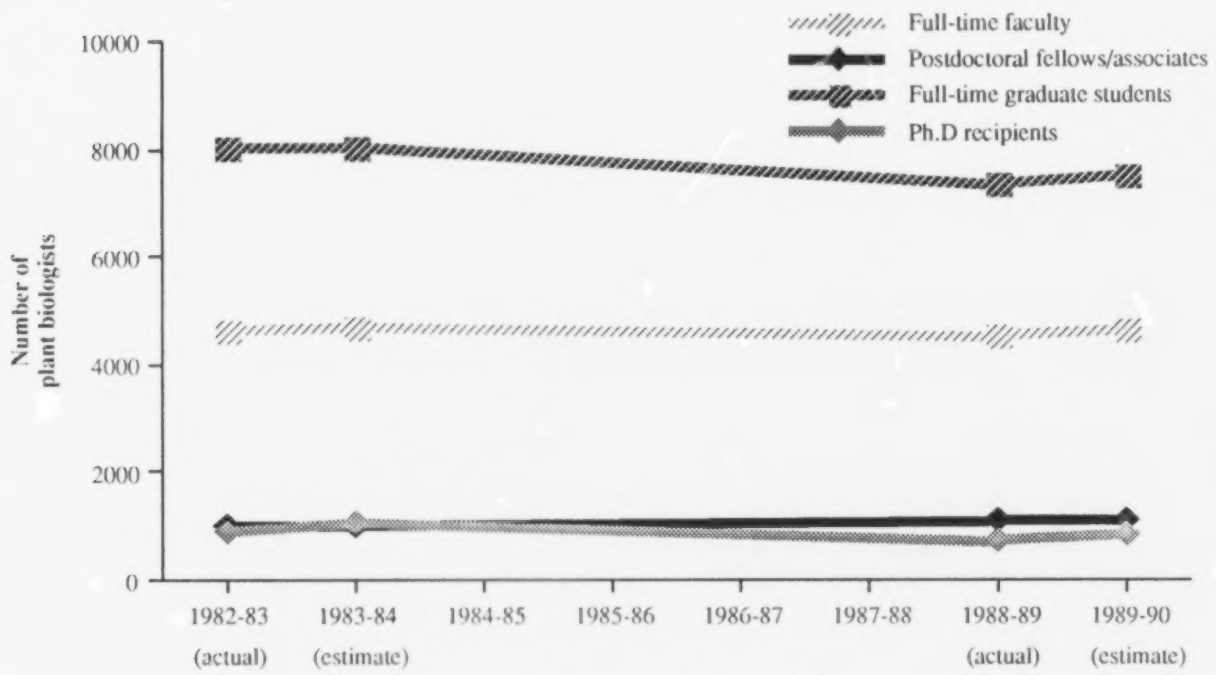
Changes Over Time in Personnel (1982-83 to 1988-89)

Even the cross-sectional data just examined provide some evidence that the field of plant biology is changing over time. Some changes could seen by comparing institutions' actual figures for 1988-89 with their projections for 1989-90, while other changes could be projected by comparing the make-up of current faculty with that of graduate students and Ph.D. recipients, the primary source of future faculty. To further explore the nature of these changes, this section will summarize the findings of the 1983 and 1989 surveys on plant biology personnel.

Figure 6 shows trends based on the four years for which the two surveys provide data: 1982-83 and 1988-89 (actual data), and 1983-84 and 1989-90 (estimates by plant biology program representatives). For three key numbers -- the numbers of full-time

[6]Data on all of the agricultural and biological sciences are from **Science and Engineering Doctorates, 1960-89**, Surveys of Science Resources Series, National Science Foundation, NSF 90-320, Detailed Statistical Tables, Table 1, p. 22 (Washington, D.C., 1990).

Figure 6. The number of plant biologists at doctorate-granting institutions, selected years from 1982-83 to 1989-90: United States



Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

graduate students, full-time faculty, and Ph.D. recipients -- the graph shows long-term declines. The number of full-time faculty shows a net decline of 2 percent from 1982-83 to 1988-89, the number of graduate students a decline of 9 percent, and the number of Ph.D. recipients a decline of 22 percent. Interestingly, these figures represent a reversal of trends that might have been predicted from the 1983 survey, when institutions projected slight increases in all three areas for the following year. In contrast, the number of postdoctoral fellows and associates shows a long-term increase from 1,009 in 1982-83 to 1,120 in 1989-90 (11 percent).[7] The percentage of faculty training graduate students declined slightly from 81 percent in 1982-83 (based on the 1984 report) to 79 percent in 1988-89.

[7]Several of these statistics show variation from one year to another, with both increases and decreases depending on the years examined. However, the general trends appear sufficiently large to speak meaningfully of net changes. Data are not available from this survey to examine the degree to which some of the year-to-year fluctuations may be artifacts of the way in which data were collected. Especially in the case of Ph.D. recipients, it is surprising to see projected increases both from 1982-83 to 1983-84, and from 1988-89 to 1989-90, in contrast to actual overall declines. One possibility is that the projected increases represent graduate students' optimistic projections of when they would complete their degrees, while their actual progress may have been slower than anticipated. Similarly, one could argue that the relatively large projected drop (compared to previous years) in the number of full-time faculty from 1988-89 to 1989-90 represents an inability of program representatives to project the number of departing faculty that will be successfully replaced; however, no such similar drop was found from 1982-82 to 1983-84, lessening the justification for such an explanation.

Along with changes in the total number of plant biologists, the distribution by gender and minority status also changed. The percentage of females increased at least marginally in three of the four categories. The changes from 1982-83 to 1988-89 were from 7 percent to 10 percent among full-time faculty, from 21 percent to 27 percent among Ph.D. recipients, and from 31 percent to 33 percent among graduate students; there was no change among postdoctoral fellows, which remained stable at 29 percent. While a somewhat greater proportion of graduate students and postdoctoral fellows and associates were females among U.S. citizens than among noncitizens (noted earlier), this difference did not have an important effect on changes over time. Among U.S. citizens, the percentages increased from 34 percent to 37 percent among graduate students, and remained stable at 34 percent among postdoctoral fellows and associates.

The percentage of all plant biologists who were racial/ethnic minorities and U.S. citizens increased as well.[8] The increases were from 7 percent to 9 percent among full-time graduate students, from 5 percent to 10 percent among Ph.D. recipients, and from 7 percent to 11 percent among postdoctoral fellows and associates. These increases are larger when percentages are calculated for plant biologists who are U.S. citizens. Racial/ethnic minorities increased: from 7 percent of graduate students in 1982-83 to 13 percent in 1988-89, and from 11 percent of postdoctorates in 1982-83 to 17 percent in 1988-89. In the case of faculty, the percentage of all full-time plant biology faculty who are racial/ethnic minorities and U.S. citizens has remained stable at 4 percent.

Finally, the number of plant biologists who were foreign has increased among graduate students from 1,612 in 1982-83 to 2,491 in 1988-89, and among postdoctoral fellows and associates from 331 in 1982-83 to 431 in 1988-89. For full-time graduate students, the increase was from 20 percent to 34 percent, while for postdoctoral fellows and associates, the increase was from 33 percent to 38 percent. Although there was a decline in the total number of graduate students from 1982-83 to 1988-89, there was an actual increase of 55 percent in the number of foreign graduate students and a 25 percent decline in the number who were U.S. citizens (from 6,411 to 4,826).

Major Disciplines Within Plant Biology

Besides providing cumulative statistics on all plant biologists at their institutions, program representatives were also asked to provide information on specific disciplines in which plant biologists at their institutions might be involved. They were asked to identify the major disciplines in their plant biology programs, the discipline with the greatest need for filling vacancies, and the disciplines with the greatest surpluses or shortages in various employment categories.

[8] As noted earlier, statistics for racial/ethnic minority groups were collected only for U.S. citizens.

Current Emphasis in Major Disciplines

Program representatives were asked to rank the top three disciplines in their plant biology programs based on the number of graduate students, postdoctorates, and faculty doing research. A list of 16 disciplines was provided, along with the option of listing additional disciplines. The listed disciplines were agronomy/soil science, anatomy/morphology, biochemistry, cell biology, developmental biology, ecology, evolution, forestry/natural resources, genetics, horticulture/crop science, microbiology, molecular biology, plant pathology, plant physiology, systematics, and weed science.

Each of the 16 listed disciplines was ranked first by at least one program representative as training the greatest number of graduate students in plant biology at his/her institution (Appendix Table A-13). For 1988-89, the disciplines ranked first most often were ecology (30 institutions), molecular biology (29), agronomy/soil science (16), plant physiology (16), and systematics (10). Additional disciplines that were selected frequently as having the second or third most students were biochemistry, cell biology, genetics, and plant pathology. When all three categories (most students, second most students, and third most students) were totaled, the disciplines with the most graduate students were ecology (66 mentions), plant physiology (65), molecular biology (61), systematics (33), agronomy/soil science (31), genetics (31), and biochemistry (29).

Fewer institutions had postdoctorates than had graduate students, and thus fewer program representatives could state the major emphases for postdoctorates (113, compared with 153 institutions listing a primary discipline for graduate students). Still, each of the 16 disciplines was listed at least once as one of the top three. The most frequently cited disciplines were molecular biology (33 first place mentions, and 55 mentions among the top three), plant physiology (18 and 41, respectively), biochemistry (16 and 31), and ecology (10 and 24).

As with graduate student training, each of the 16 disciplines was listed by at least one program representative as having the most plant biology faculty involved in research. The disciplines listed as having the most faculty researchers were molecular biology (24 program representatives giving first place rankings), ecology (21), plant physiology (21), systematics (13), agronomy/soil science (12), biochemistry (11), and cell biology (11). The disciplines listed most often among the top three were plant physiology (72), ecology (61), molecular biology (60), and systematics (34).

In 1982-83 (Table 3), ecology was ranked most often as the discipline with the most graduate students being trained and the area where the most faculty were conducting research. Most postdoctoral training was done in plant physiology.

Table 3. Highest ranking areas of concentration in plant biology, academic years 1982-83 and 1988-89: United States

Area of concentration 1982-83	Rank	Area of concentration 1988-89
Graduate Student Training		
Ecology	1	Ecology
Plant physiology	2	Molecular biology
Systematics	3	Plant physiology
Agronomy and soil science	4	Systemics
Biochemistry	5	Genetics
Faculty Research		
Ecology	1	Plant physiology
Plant physiology	2	Ecology
Systematics	3	Molecular biology
Biochemistry	4	Biochemistry
Agronomy and soil science	5	Genetics
Postdoctoral Training and Research		
Plant physiology	1	Molecular biology
Biochemistry	2	Plant physiology
Ecology	3	Biochemistry
Plant pathology	4	Ecology
Molecular biology	5	Agronomy/soil science

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 6, p. 20.

Filling Vacancies in Major Disciplines

Program representatives had some difficulty describing their vacancies in plant biology because the field spans many disciplines, many which include fields other than plant biology. In some cases, they expected departments at their institutions to have vacancies due to the departure of faculty, but the positions could potentially be assigned to other disciplines at the institution and had to be re-authorized before recruiting could begin. In other cases, they indicated their institutions might be actively recruiting in areas such as cell biology or biochemistry, without any prior determination of whether the candidate should also be a plant biologist. To lessen ambiguities in their responses, program representatives were asked to describe the number of full-time vacancies specifically in plant biology for which they were actively recruiting.

Of 154 institutions with graduate programs in plant biology in 1988-89, 82 program representatives reported their institutions were actively recruiting for a total of 276 full-time vacancies in plant

biology. In comparison, in 1982-83, program representatives indicated there were 213 vacancies. The 276 vacancies in 1988-89 average to roughly 3 vacancies per institution (Appendix Table A-14). By far, the greatest number of vacancies (236, or 86 percent) were at public institutions, with 209 (76 percent) at land-grant institutions. One-fifth (56) of the vacancies were at the 20 largest institutions based on federally financed research and development expenditures in the life sciences, and two-thirds were at institutions with a large plant biology faculty (26 members or more). The greatest number of vacancies (102, or 37 percent) were at institutions located in the Southeast, the region currently having the greatest number of plant biology faculty.

The area in which program representatives expressed the greatest need to fill vacancies was molecular biology (33 percent of all institutions with vacancies). The next most frequently expressed need was in plant physiology (11 percent). Program representatives at land-grant institutions were somewhat more likely to say their greatest need was in molecular biology (35 percent) than private institutions (27 percent). Molecular biology was also listed as the greatest need more often by program representatives at the 20 institutions with the largest federally financed R&D expenditures in the life sciences (44 percent, compared with 30 percent of the other institutions), and by those at institutions with fewer faculty (40 percent of those at institutions with 25 or fewer plant biology faculty, compared with 26 percent of those with 26 or more faculty).

However, these differences were not large, and in some cases the percentages were based on small numbers of institutions (since not all program representatives reported their vacancies in plant biology). Needs in plant physiology were even more consistently reported across institutions.

Program representatives who stated their institutions had vacancies in plant biology and gave the discipline in which they had the greatest need were asked to provide the reason for the need. The most commonly cited reasons were research opportunities (48 percent) and faculty retirements and departures (42 percent). Departmental representatives at institutions in the Southeast were more likely to give research opportunities as the reason (57 percent) than those in the Northeast (40 percent), and those at public institutions (50 percent) more so than those at private institutions (36 percent). Another difference was that 54 percent of program representatives at institutions with 26 or more plant biology faculty cited faculty retirements and departures, compared with 26 percent of those at institutions with between 6 and 25 plant biology faculty.

Current Employment Market in Plant Biology

Using the list of 16 disciplines described above, program representatives were asked to identify the 2 disciplines where they were most experiencing a surplus of positions and the 2 where they were most experiencing a shortage for 6 employment categories: postdoctoral training positions, permanent doctoral research associate positions, tenure-track faculty positions, industrial

positions, federal/state government positions, and nonprofit research institutions. A surplus of positions was defined as there are more positions available than trained people to fill them, and a shortage as there are not enough positions for all the qualified people who are applying for them. Not all program representatives were able to respond for all six of the categories, and some program representatives often lacked experience with the employment market in the industrial, federal/state, and nonprofit research institution employment categories. Some of the program representatives at smaller institutions also expressed difficulties with answering this item because of limited experience with all 16 disciplines, and were reluctant to list 2 disciplines when they lacked information on other disciplines. For this reason, percentages are not presented in this section, but the absolute number of program representatives citing an area as one of the two most experiencing a surplus or shortage.

In both 1982-83 and 1988-89, molecular biology was mentioned most frequently as the discipline with a surplus of positions; the disciplines most often cited as having a shortage of positions were ecology in 1982-83 and systematics in 1988-89 (Tables 4 and 5). In each of the six employment categories, program representatives were most likely to indicate a surplus of positions for molecular biology in 1988-89. For example, program representatives at 47 institutions said there was a surplus of tenure-track faculty positions, compared with program representatives at 26 institutions saying there was a shortage (Appendix Table A-15). Biochemistry was also cited frequently: although overall program representatives tended to describe biochemistry as experiencing a surplus of positions, in some employment categories (permanent doctoral research associate, government, and nonprofit research institutions), program representatives were relatively evenly divided between those seeing a surplus and those seeing a shortage.

Systematics, anatomy/morphology, and evolution generally were seen as experiencing a shortage of positions in all six employment categories. For example, in systematics, program representatives at 30 institutions saw a shortage of tenure-track faculty positions, compared with those at 5 institutions who saw a surplus. In anatomy/morphology, representatives at 20 institutions said there was a shortage in tenure-track faculty positions, compared with 3 saying there was a surplus; and in evolution, 11 said there was shortage, compared with 2 seeing a surplus.

Changes in Major Disciplines (1982-83 to 1988-89)

In some cases, there were dramatic changes in disciplines program representatives listed among the top three in faculty research. The greatest increase occurred in molecular biology, which was listed as one of the top three disciplines in faculty research by 20 program representatives in 1982-83, but by 60 program representatives in 1988-89 (Figure 7). Given that many program representatives

Table 4. Disciplines frequently cited by program representatives as having a shortage of positions by employment category, academic years 1982-83 and 1988-89: United States

Employment category	Academic year	Most frequently cited	Second most frequently cited
Postdoctoral training positions	1982-83	Ecology	Systematics
	1988-89	Systematics	Ecology
Permanent doctoral research associate positions	1982-83	Ecology	Anatomy/morphology
	1988-89	Systematics	Ecology
Tenure-track faculty positions	1982-83	Ecology	Systematics
	1988-89	Systematics	Ecology
Industrial positions	1982-83	Ecology	Systematics
	1988-89	Molecular biology	Systematics
Federal/state government positions	1982-83	Ecology	Systematics
	1988-89	Systematics	Molecular biology
Nonprofit research institutions	1982-83	n.a.	n.a.
	1988-89	Systematics	Molecular biology

n.a. = not available; not asked in 1984.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989), and Plant Biology and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 9b, p. 20.

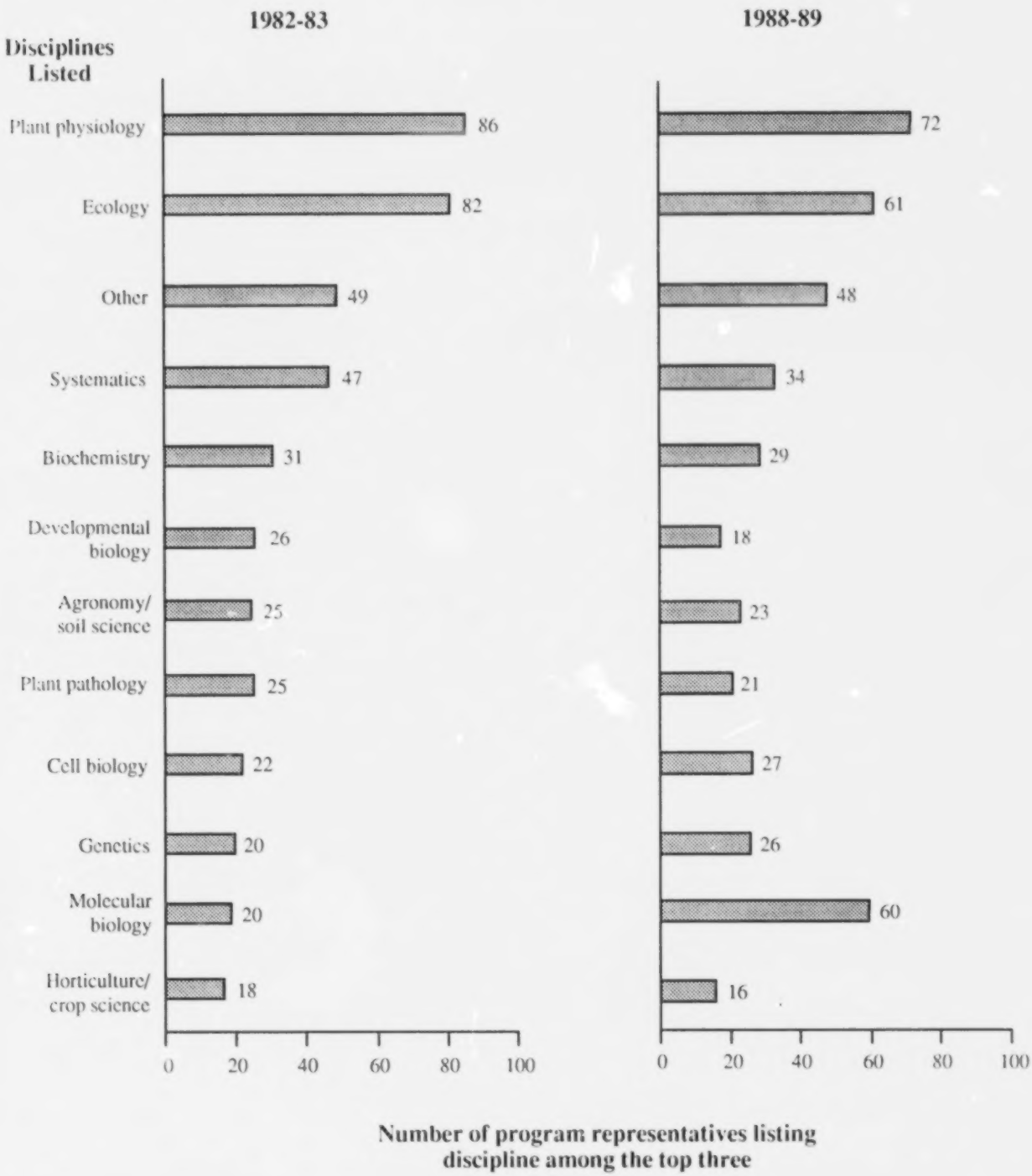
Table 5. Disciplines frequently cited by program representatives as having a surplus of positions by employment category, academic years 1982-83 and 1988-89: United States

Employment category	Academic year	Most frequently cited	Second most frequently cited
Postdoctoral training positions	1982-83	Molecular biology	Biochemistry
	1988-89	Molecular biology	Biochemistry
Permanent doctoral research associate positions	1982-83	Molecular biology	Biochemistry
	1988-89	Molecular biology	Biochemistry
Tenure-track faculty positions	1982-83	Molecular biology	Genetics
	1988-89	Molecular biology	Biochemistry
Industrial positions	1982-83	Molecular biology	Biochemistry, Genetics
	1988-89	Molecular biology	Biochemistry
Federal/state government positions	1982-83	Molecular biology	Biochemistry
	1988-89	Molecular biology	Biochemistry
Nonprofit research institutions	1982-83	n.a.	n.a.
	1988-89	Molecular biology	Biochemistry

n.a. = not available; not asked in 1984.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 9a, p. 25.

Figure 7. Disciplines program representatives listed among the top three (based upon greatest number of faculty) in faculty research in 1982-83 and 1988-89: United States



Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

perceived a surplus of positions in molecular biology in 1988-89, the number of biologists trained in molecular biology may increase further. Other disciplines showed large declines in the number of program representatives that listed them as one of their top three in faculty research; ecology changed from 82 mentions in 1982-83 to 61 mentions in 1988-89, plant physiology from 86 to 72, and systematics from 47 to 34.

Changes also occurred with respect to the employment market. The number of vacancies for which program representatives indicated their institutions were actively recruiting increased from 213 vacancies at 67 institutions in 1982-83 to 276 vacancies at 82 institutions in 1988-89 (Table 6). The disciplines in which program representatives reported the greatest need for faculty changed from molecular biology (27 percent), horticulture/crop science (12 percent), and agronomy/soil science (10 percent) in 1982-83 to molecular biology (33 percent) and plant physiology (11 percent) in 1988-89. Also, though the proportions of program representatives giving reasons for needing to fill vacancies did not change substantially, more program representatives indicated their institution experienced vacancies in 1988-89, and thus the number choosing the two major reasons increased (Figure 8). For example, research opportunities was the major reason given for needing to fill vacancies, and the number of program representatives giving that reason increased from 35 in 1982-83 (52 percent) to 39 in 1988-89 (48 percent). Similarly, the second major reason, faculty retirements and departures, was cited by 24 program representatives in 1982-83 (36 percent) and by 34 program representatives in 1988-89 (42 percent).

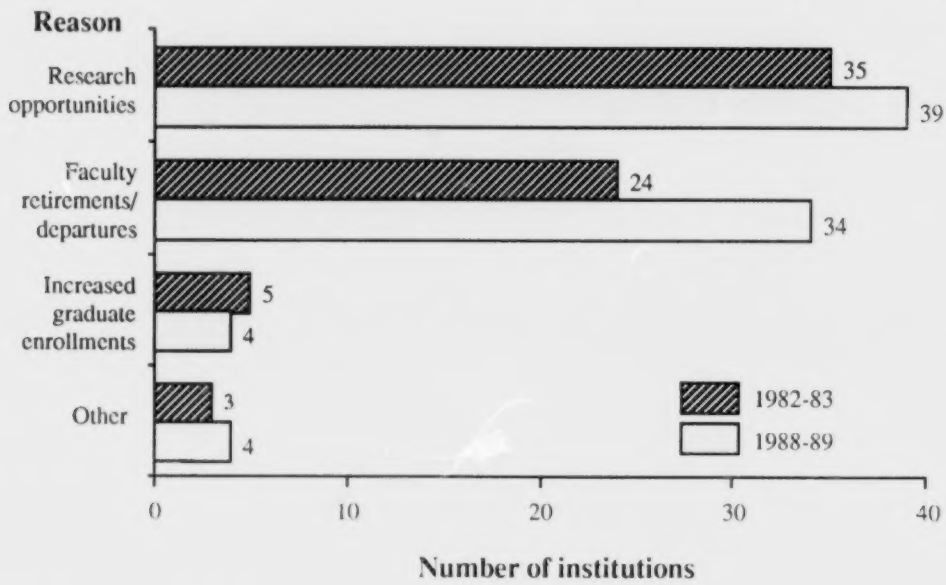
Table 6. Number of faculty vacancies in plant biology, academic years 1982-83 and 1988-89: United States

Institutional characteristic	1982-83	1988-89
Total	213	276
Control		
Public	190	236
Land-grant	168	209
Private	23	40
Research size		
Top 20	61	56
Not in top 20	152	220

NOTE: Research size is based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 8a, p. 23.

Figure 8. Reasons program representatives selected for their institution's "greatest need" to fill vacancies in plant biology in 1982-83 and 1988-89: United States



NOTE: One institution with vacancies did not provide a reason for the greatest need.

Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

Financial Support

Program representatives were asked to describe the amount of outside financial support their institution had received for plant biology research, and the major source of funding for graduate student and postdoctoral fellows/associates at their institutions.

Research

Program representatives had difficulties in determining the amount of outside funding for plant biology. One problem was that their institutions were not structured to deal with plant biology as a single discipline, but rather often offered plant biology in many different departments, some of which also included fields other than plant biology. Even when institutions had strong institutional controls for monitoring finances, those controls typically were not designed for monitoring plant biology. Further, at some institutions, grants were managed in a decentralized manner (e.g., through the indicated

researchers) with little institution-wide information about those grants. Thus, five program representatives could not provide any data on outside funding for their institution, and others expressed uncertainty over the figures that they provided.

NSF maintains data on federal funding for plant biology available through competitive grants, and these data were compared with the survey data to evaluate the reliability of the latter. The NSF data listed $150 million for 1988-89 (compared to $120 million based on this survey) and confirmed that the amounts reported for the institutions surveyed were underestimates of the total amount received for federal funding. No data were available for evaluating the other nonfederal components of outside funding, but feedback from program representatives indicates that all figures provided in this survey are likely to be underestimates. They could clearly report on some grants for plant biology, but not all grants could be identified.

For fiscal year 1988-89, program representatives reported $242 million in outside support for plant biology research (Appendix Table A-16).[9] This compares with a total outside funding of $6 billion for all of the life sciences, and $112 million in federal Hatch funds for all of the life sciences.[10] Roughly half of this support, according to the program representatives, came from the federal government (8 percent in Hatch funds, and 41 percent from other federal government sources).[11] The primary nonfederal source of funds for research they reported was state governments, which accounted for one-third of all support (23 percent in Hatch funds, and 11 percent from other state sources). Industry provided 9 percent of all outside funds for research, and other private sources (e.g., foundations and associations) provided 8 percent.

Consistent with the finding that most plant biologists were located at public institutions, program representatives at public institutions reported $224 million (93 percent) of outside funding for research, and $212 million (88 percent) was reported by program representatives at land-grant institutions. The 20 largest institutions (based on federally financed research and development expenditures in the life sciences in 1988) received $76 million, or 31 percent. Based on faculty size, research funds went primarily to the institutions with

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[9] Where institutional representatives were unable to provide exact numbers, they were asked to provide their best estimates. Five institutional representatives were not able to provide any data on the amount of outside funding received for plant biology. Using a regression equation ($r2 = .67$) based on the number of full-time graduate students, Ph.D. degrees awarded, and postdoctorates, an additional $12 million above the $242 million reported here might be estimated to have been received at those institutions.

[10] Estimate of total outside funding based on $7.2 billion in R&D expenditures in the life sciences, and on 83 percent of R&D expenditures for all sciences coming from outside sources. Published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, op. cit. Information on Hatch funds is from the Cooperative State Research Budget Office.

[11] For roughly 4 percent of the funds, institutional representatives were able only to provide totals, rather than indicating the specific source of funds. Percentages provided here on the source of funds are based on the 96 percent of funds where data were available.

the largest programs, with $201 million (83 percent) reported by program representatives at institutions with 26 or more plant biology faculty. Although program representatives at institutions in the West reported fewer full-time plant biology faculty than both those in the Southeast and Central regions, they reported more funds than either ($97 million, or 40 percent); this was due to the greater level of state government Hatch funds reported (38 percent of all plant biology research funds in the West, compared with no more than 14 percent in the other regions). The region in which program representatives reported the second most funds, the Southeast, was distinguished by its relatively large level of other state government funds besides Hatch funds (20 percent, compared with from 6 to 9 percent of funds reported in other regions).

At one-third of all reported funding, Hatch funds formed a major portion of the financial support for plant biology research. Hatch funds are provided on a matching basis from the federal and state governments to agricultural experiment stations, with states varying in the percentage match they provide for the federal funds. As noted, the relatively high level of state support reported in the West resulted in high total funding in that region. Hatch funds were not large enough to account for all of the difference between public and private institutions, or between large and small institutions, but did account for a major part of that difference.

Graduate Students

Graduate students may receive financial support from many sources, and a student may receive support from a combination of sources. Program representatives were asked to describe their plant biology graduate students' support in terms of the major source of support for each student.

The most frequently mentioned primary source of funds was institutional support, which was the major source for 28 percent of all graduate students in 1988-89 (Appendix Table A-17) and 30 percent in 1982-83 (Appendix Table A-18). However, if federal, state, and foreign funds are combined, half of the students received their major support from government funds: 21 percent of all graduate students were primarily supported by federal research grants, 4 percent by federal fellowships, 15 percent by state government sources, and 10 percent by foreign governments. Students were also supported through personal funds (11 percent), industry (5 percent), and other sources (6 percent).

Some of the greatest differences among institutions were in the program representatives' reports of support of students by state governments. Those at public institutions reported state governments were the primary source of support for 15 percent of the graduate students, compared with 2 percent reported for those at private institutions. Since public institutions had many more graduate students than private institutions (6,878 versus 439), differences were even larger in terms of absolute numbers of students. Also, program representatives at institutions with 26 or more plant biology faculty reported both a greater percentage

(17 percent) and greater absolute number of students primarily supported by state governments than those at smaller institutions (7 percent or fewer).

Support by foreign governments followed similar patterns, with greater percentages of support reported for public institutions (10 percent of students) than for private institutions (5 percent), and for institutions with 26 or more plant biology faculty (12 percent) than for smaller institutions (3 percent). This is consistent with the much greater percentage of foreign students at public institutions and large institutions noted earlier.

Postdoctoral Fellows and Associates

Postdoctoral fellows and associates in 1988-89 received support from different sources than did graduate students, especially the federal government. Program representatives indicated that most of their postdoctorates (52 percent) received their primary support from federal research grants, and an additional 7 percent from federal fellowships (Appendix Table A-19). Figures for 1982-83 were very similar -- 54 percent from federal grants and 6 percent from federal fellowships (Appendix Table A-20). Other primary sources of support in 1988-89 were state governments (12 percent of postdoctorates), industry (7 percent), foreign governments (6 percent), institutional support (6 percent), personal funds (3 percent), and other sources (6 percent).

According to program representatives a greater percentage of postdoctorates were supported by federal research grants at public institutions (55 percent) and institutions with 26 or more plant biology faculty (53 percent) than at private institutions (36 percent) or institutions with 5 or fewer faculty (33 percent). Instead, private institutions and institutions with five or fewer faculty showed higher levels of support by federal fellowships (17 percent and 21 percent, respectively) than institutions overall (7 percent).

Changes in Financial Support (1982-83 to 1988-89)

Total reported outside support for plant biology research increased from $201.6 million in 1982-83 to $242.5 million in 1988-89, an increase of 20 percent (1982-83 data from the 1984 plant biology report).[12] The Consumer Price Index (CPI) showed an inflation rate of 23 percent from 1982 to 1988, so this increase was very close to (but slightly lower than) the rate of inflation. Since program representatives reported a small decline in the number of full-time faculty in plant biology, the amount of financial support per full-time faculty member increased at a somewhat higher rate (23 percent), the same as the rate of inflation.

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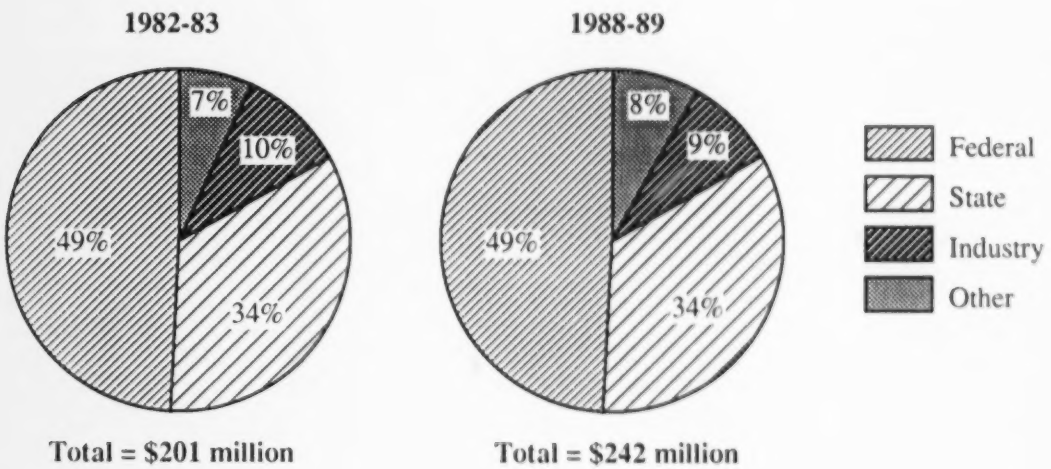
[12] As noted, the figures for 1988-89 are underestimates. NSF data on federal funding for plant biology corresponded more closely to the survey data for 1983-84 than for 1988-89. Thus, these figures may underestimate the amount of growth that has occurred. Another explanation might be that the quality of NSF data on Federal funding of plant biology has improved since 1983-84, and represents federal funding more completely than it did earlier.

The sources of outside funds reported by program representatives were relatively stable in terms of the proportion of dollars provided (the federal government accounted for 49 percent of funds both in 1982-83 and in 1988-89, and state governments accounted for 34 percent in both years), though the dollar amounts increased from each source over that time period (Figure 9).

Figure 9. Program representatives' report of outside financial support for plant biology research in 1982-83 and 1988-89: United States

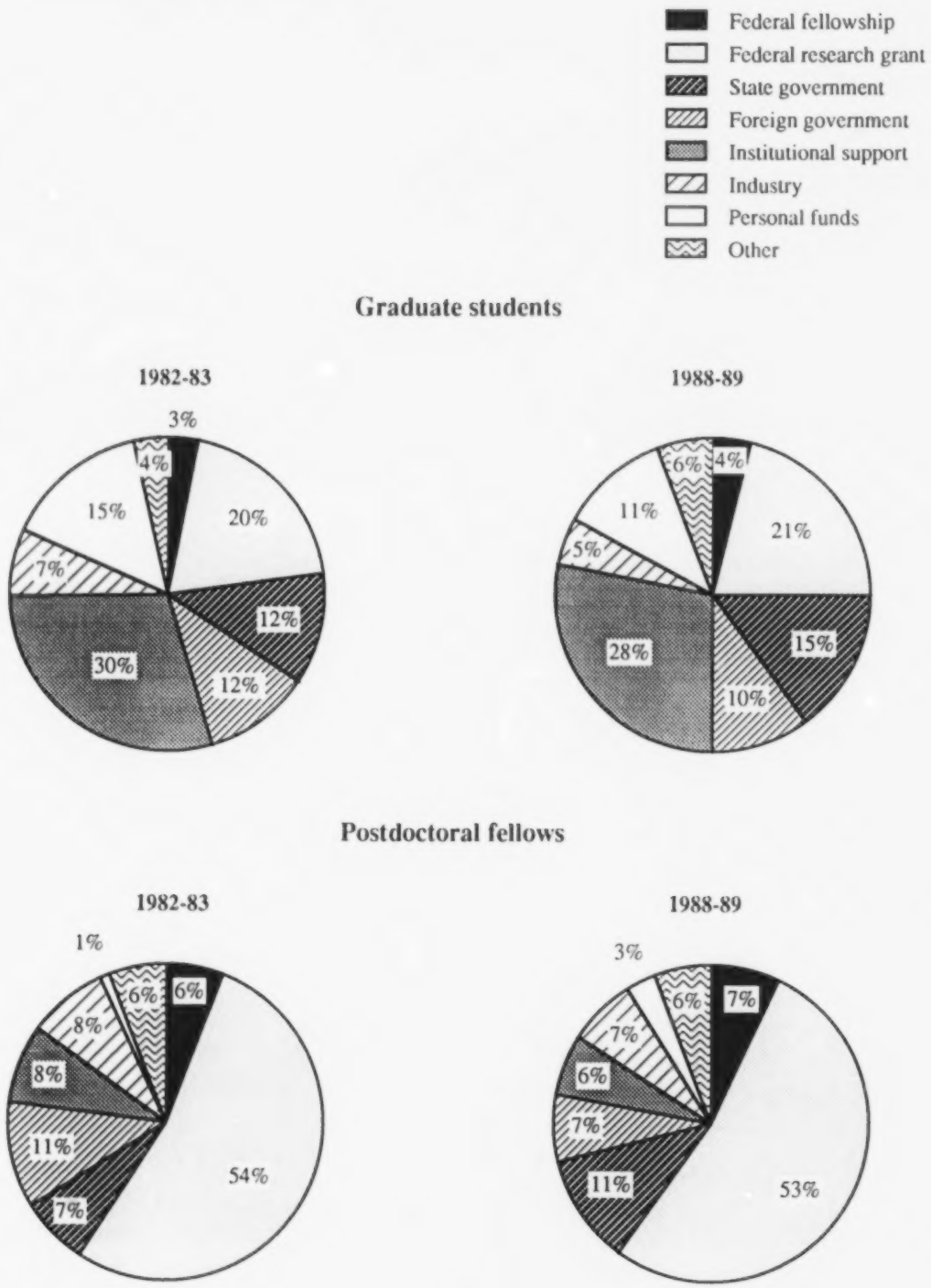


NOTE: The total dollar amount for 1988-89 is known to be an underestimate, due to the institutional difficulties in identifying all plant biology funds. Percentage estimates on the sources of funds are based on the 96% of funds for which institutions could identify sources.

Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

There was very little change in the major sources of financial support for graduate students and postdoctoral fellows from 1982-83 to 1988-89 in terms of the proportion receiving each type of support (Figure 10).

Figure 10. Major source of support for graduate students and postdoctoral fellows in 1982-83 and 1988-89: United States



NOTE: Percentages may not add to 100 due to rounding.

Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education.

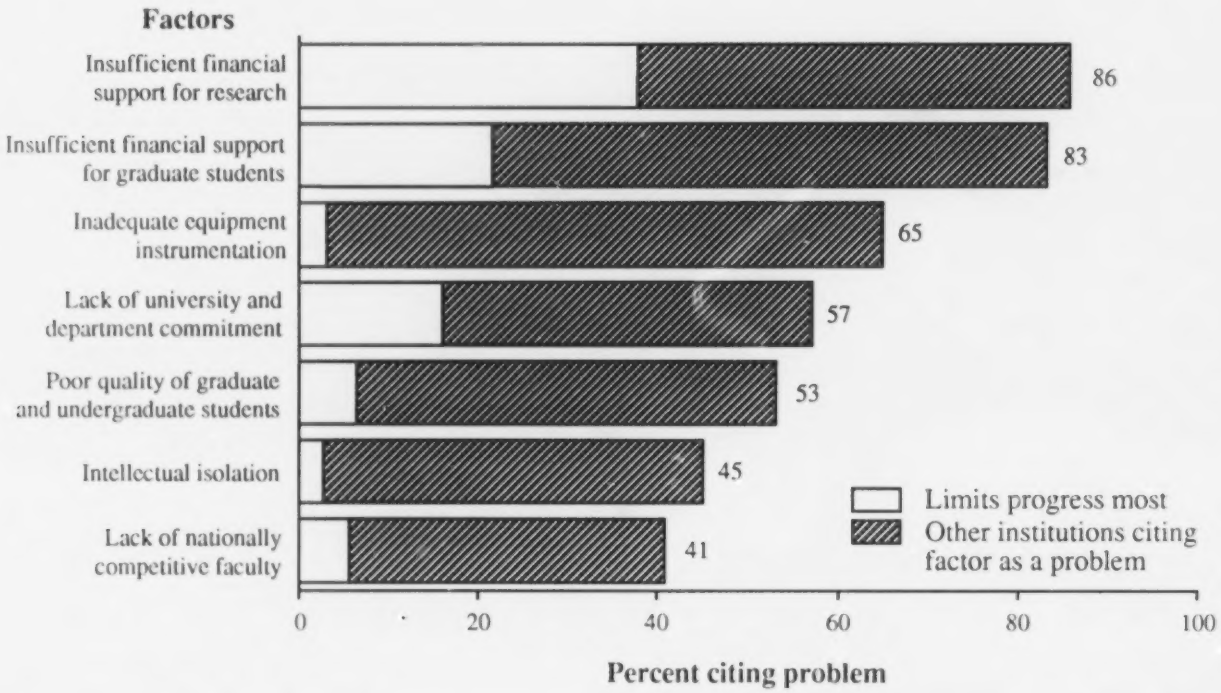
Factors Limiting Progress in Plant Biology

Program representatives were asked to state whether each of seven listed factors had the effect of limiting progress in plant biology at their institutions. The factors included intellectual isolation, insufficient financial support for research, poor quality of graduate and undergraduate students, lack of nationally competitive faculty, inadequate equipment/instrumentation, insufficient financial support for graduate students, and lack of university and department commitment to plant biology. Of those factors that did limit progress, they were asked to rank them in terms of which limited progress the most (i.e., "1" for the area that limits progress the most, "2" for the second most, etc.).

Each factor was listed as a problem by at least two-fifths of the program representatives. In order of the frequency of mention, they were insufficient financial support for research (86 percent), insufficient financial support for graduate students (83 percent), inadequate equipment/instrumentation (65 percent), lack of university and department commitment to plant biology (57 percent), poor quality of graduate and undergraduate students (53 percent), intellectual isolation (45 percent), and a lack of a nationally competitive faculty (41 percent; Appendix Table A-21). Additionally, 12 percent of the program representatives listed other problems besides the 7 listed in the questionnaire. The mean ranks resulted in a roughly similar ordering, with insufficient financial support for research and insufficient financial support for graduate students being problems that limited progress the most (the mean ranks were 1.9 and 2.5, respectively). However, while 65 percent of program representatives said that they were limited by inadequate equipment instrumentation, few said this was the factor limiting progress the most (Figure 11).

For six of the seven problems listed, program representatives at public institutions were more likely than those at private institutions to perceive a problem. The exception was a lack of university and department commitment to plant biology, where the percentages were essentially equal. However, representatives of public and private institutions ranked the factors in essentially the same order, except that those at private institutions gave a greater importance to a lack of university and department commitment to plant biology (mean rank of 2.7) than those at public institutions (mean rank of 3.8). Similarly, for every factor but intellectual isolation and a lack of university and department commitment to plant biology, program representatives at institutions with 26 or more plant biology faculty were more likely to perceive a problem than institutions with 5 or fewer plant biology faculty. Again, the relative ranks of the seven factors were roughly similar among the two groups, except that those at institutions with five or fewer faculty gave more importance to intellectual isolation (mean rank of 3.8, compared with 5.3 for those at institutions with large plant biology programs) and a lack of university and department commitment to plant biology (mean ranks of 3.0 and 5.0, respectively).

Figure 11. Program representatives' evaluation of factors limiting progress in plant biology, academic year 1988-89: United States



Source: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (1989 survey).

APPENDIX A

DETAILED TABLES

NOTE: When available, tables containing results from 1984 survey will immediately follow comparable tables with 1989 survey results.

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Table A-1. Administrative unit that has primary focus for training graduate students in plant biology by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Number of institutions		Location of primary focus (percent)					
			Division/ College of Arts and Sciences		School/College/ Division of Agriculture/ Forestry/ Natural Resources		Other administrative unit	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	154	100	96	62	52	34	6	4
Control								
Public	113	100	61	54	49	43	3	3
Land-grant[1]	89	100	42	47	45	51	2	2
Private	41	100	35	85	3	7	3	7
Research size[2]								
Top 20	20	100	16	80	4	20	0	0
Not in top 20	134	100	80	60	48	36	6	4
Plant biology faculty								
1 - 5	47	100	46	98	0	0	1	2
6 - 25	60	100	45	75	11	18	4	7
26 or more	47	100	5	11	41	87	1	2
Region								
Northeast	34	100	24	71	8	24	2	6
Central	43	100	29	67	12	28	2	5
Southeast	45	100	27	60	17	38	1	2
West	32	100	16	50	15	47	1	3

[1]One land-grant institution is a private institution that has been granted the use of some public land.

[2]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

NOTE: Percentages may not add to 100 due to rounding.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-2. Administrative unit that has primary focus for training graduate students in plant biology by institutional characteristic, academic year 1982-83: United States

Institutional characteristic	Number of institutions		Location of primary focus					
			Division/ College of Arts and Sciences		School/College/ Division of Agriculture/ Forestry/ Natural Resources		Other administrative unit	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	165	100	89	54	49	30	27	16
Control								
Public	118	100	56	47	43	36	19	16
Land-grant	48	100	5	10	41	85	2	4
Private	47	100	33	70	5	11	9	19
Research size*								
Top 20	20	100	13	65	5	25	2	10
Not in top 20	145	100	76	52	44	30	25	17

*Based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

NOTE: Details may not add to totals because of rounding.

SOURCE: Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 1, p. 12.

Table A-3. Number of full-time plant biology faculty and the percent training graduate students by institutional characteristic and department type, academic year 1988-89: United States

Discipline	All institutions		Control						Research size[1]			
			Public				Private		Top 20		Not in top 20	
			All		Land-grant[2]							
	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students
Total[3]	4,517	79	4,237	79	3,671	79	280	87	717	90	3,800	78
Botany	589	94	544	93	512	93	45	98	72	100	517	93
Plant science	226	87	216	88	226	87	10	70	25	88	201	87
Agronomy and soil science	724	76	710	76	695	76	14	79	93	90	631	74
Biology	584	83	452	81	334	81	132	88	91	95	493	80
Food sciences	297	71	286	70	231	62	11	82	56	79	241	69
Horticulture	531	75	528	76	461	78	3	0	77	84	454	74
Plant pathology	562	77	558	77	490	79	4	75	94	93	468	74
Forestry	325	73	322	73	230	69	3	100	33	94	292	71
Plant and soil science	221	71	221	71	179	78	0	--	10	60	211	72
Biochemistry	81	80	76	80	64	86	5	80	10	100	71	77
Genetics	44	75	36	69	30	67	8	100	14	100	30	63
Chemistry	17	100	15	100	9	100	2	100	3	100	14	100
Animal and range sciences	61	90	58	93	58	93	3	33	5	60	56	93
Molecular and cell biology	52	77	45	73	42	74	7	100	4	100	48	75
Ecology	45	87	43	86	43	86	2	100	31	84	14	93
Microbiology	17	94	12	100	10	100	5	80	4	100	13	92
Assorted biological sciences	28	89	15	80	9	100	13	100	12	100	16	81
All others	41	54	28	46	38	55	13	69	11	82	30	43

[1]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]The total includes 72 faculty at one institution whose departments were not identified. These 72 faculty were not included when calculating the percentage training graduate students.

NOTE: The number of departments with plant biology faculty ranged from 1 to 13 per institution.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

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Table A-4. Number of full-time plant biology faculty and the percent training graduate students by institutional characteristics and department type, academic year 1982-83: United States

Department[1]	All institutions		Control						Research size[2]			
			Public				Private		Top 20		Not in top 20	
			All		Land-grant							
	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students	Total	Percent training graduate students
Total	4,759	81	4,491	81	3,802	79	268	81	863	85	3,896	80
Botany	600	90	561	90	404	88	39	87	96	100	504	88
Plant science	313	72	313	72	313	72	0	n.a.	22	91	291	70
Agronomy and soil science	806	73	806	73	795	74	0	n.a.	52	77	754	73
Biology	428	82	284	84	74	80	144	76	64	86	364	81
Food sciences	-	-	-	-	-	-	-	-	-	-	-	-
Horticulture	506	73	506	73	506	73	0	n.a.	99	76	407	72
Plant pathology	434	82	434	82	434	82	0	n.a.	80	93	354	80
Forestry	246	79	230	77	206	79	16	100	80	79	166	79
Plant and soil science	195	71	195	71	181	69	0	n.a.	42	45	153	78
Biochemistry	109	93	106	94	100	94	3	33	33	100	76	89
Genetics	56	89	55	91	55	91	1	0	25	96	31	84
Chemistry	18	100	17	100	2	100	1	100	6	100	12	100
Animal and range sciences	-	-	-	-	-	-	-	-	-	-	-	-
Molecular and cell biology	-	-	-	-	-	-	-	-	-	-	-	-
Microbiology	-	-	-	-	-	-	-	-	-	-	-	-
Assorted biological sciences	205	87	182	86	54	83	23	100	23	100	182	86
Marine sciences/oceanography	13	100	13	100	1	100	0	--	3	100	10	100
All others	830	87	789	87	677	87	41	78	238	85	592	87

[1] Department names cited by 5 or more institutions.

[2] Based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

- = Data not available in the 1984 report.

n.a. = not applicable.

NOTE: This table shows counts of plant biology faculty in departments that were involved in training plant biology graduate students. Table A-6 shows counts of faculty in plant biology programs.

SOURCE: Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Tables 2a, b & c, pp. 13-15.

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Table A-5. Number of full-time faculty in plant biology programs[1], and the percentage female and racial/ethnic minorities, by institutional characteristic, academic years 1982-83 and 1988-89: United States

Institutional characteristic	1989 survey				1983 survey			
	Total full-time faculty[2]		Percentage of full-time faculty in 1988-89 who were:		Total full-time faculty[3]		Percentage of full-time faculty in 1982-83 who were	
	1988-89	1989-90 (estimate)	Female	Racial/ ethnic minorities	1982-83	1983-84 (estimate)	Female	Racial/ ethnic minorities
Total	4,517	4,611	10	4	4,607	4,660	7	4
Control								
Public	4,237	4,344	10	4	4,344	4,440	6	4
Land-grant[4]	3,733	3,835	10	4	3,674	3,720	6	4
Private	280	267	15	4	263	260	16	8
Research size[5]								
Top 20	717	717	13	4	784	800	7	2
Not in top 20	3,800	3,894	10	4	3,823	3,860	5	5
Plant biology faculty[6]								
1-5	155	146	16	5				
6-25	714	719	16	3				
26 or more	3,648	3,746	9	4				
Region[6]								
Northeast	480	503	13	3				
Central	1,250	1,274	11	2				
Southeast	1,643	1,659	9	4				
West	1,144	1,175	11	6				

[1]Includes all full-time faculty in plant biology programs, not just those training students.

[2]This column includes only racial/ethnic minorities who are native born U.S. citizens. No data were collected on the number of non-U.S. citizens among the faculty.

[3]Includes U.S. citizens and non-U.S. citizens with permanent visas.

[4]One land-grant institution is a private institution that has been granted the use of some public land.

[5]Based on federally financed R&D expenditures in the life sciences for fiscal years 1982 and 1988.

[6]This information is not in the 1984 report.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation (survey conducted in 1989), and Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Tables 3 and 4, pp. 16-17.

Table A-6. Number of full-time faculty in plant biology, and the percentage training graduate students, and having bachelor's degrees from foreign institutions, by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Total full-time faculty	Percentage of full-time faculty in 1988-89 who were		
	1988-89	Training graduate students	With bachelor's degrees from foreign institutions	
			Total	Teaching undergraduates
Total	4,517	80	7	5
Control				
Public	4,237	79	7	4
Land-grant[1]	3,733	79	7	4
Private	280	87	16	15
Research size[2]				
Top 20	717	90	12	9
Not in top 20	3,800	78	6	4
Plant biology faculty				
1 - 5	155	85	17	15
6 - 25	714	84	11	11
26 or more	3,648	79	6	3
Region				
Northeast	480	85	10	9
Central	1,250	89	7	5
Southeast	1,643	71	4	2
West	1,144	78	10	6

[1]One land-grant institution is a private institution that has been granted the use of some public land.

[2]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-7. Number of postdoctoral fellows/associates in plant biology, and the percentage female, racial/ethnic minorities, and foreign, by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Total postdoctoral fellows/associates		Percentage of postdoctoral fellows/associates in 1988-89 who were					
				Minority racial/ethnic group[1]		Foreign		
	1988-89	1989-90 (estimate)	Female	Among all post-doctorates	Among U.S. citizens	Males	Females	From developing countries
Total	1,120	1,129	29	11	17	30	9	16
Control								
Public	964	974	29	11	17	29	8	17
Land-grant[2]	890	893	29	11	17	29	8	17
Private	156	155	32	11	20	35	11	13
Research size[3]								
Top 20	333	323	33	7	10	26	8	11
Not in top 20	787	806	28	12	21	32	9	18
Plant biology faculty								
1 - 5	67	63	25	15	28	34	12	24
6 - 25	277	283	34	9	14	30	10	13
26 or more	776	783	28	11	17	30	8	17
Region								
Northeast	108	106	36	7	13	31	14	11
Central	330	331	30	5	8	29	8	18
Southeast	279	290	23	17	32	37	10	23
West	403	402	32	11	17	25	7	12

[1]Data on minorities were collected only for postdoctorates who were U.S. citizens.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-8. Number of postdoctoral fellows/associates in plant biology programs, and the percentage female and racial/ethnic minorities, academic year 1982-83: United States

Institutional characteristic	Total postdoctoral fellows/ associates		Percentage of postdoctoral fellows/ associates in 1982-83 who were				
					Foreign		
	1982-83	1983-84 (estimate)	Female	Racial/ ethnic minorities[1]	Males	Females	From developing countries
Total	1,009	1,020	29	7	26	6	13
Control							
Public	871	860	28	7	28	7	14
Land-grant	731	730	28	6	27	7	12
Private	138	160	38	7	17	4	8
Research size[2]							
Top 20	398	400	29	4	22	5	8
Not in top 20	611	620	29	9	29	8	16

[1]Includes only racial/ethnic minorities who are also U.S. citizens and non-U.S. citizens with permanent visas.

[2]Based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

SOURCE: Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Tables 3, 4, and 5 pp. 16-19.

Table A-9. Number of full-time graduate students in plant biology, and the percentage female, racial/ethnic minorities, and foreign, by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Total full-time graduate students		Percentage of full-time graduate students in 1988-89 who were					
	1988-89	1989-90 (estimate)	Female	Minority racial/ethnic group[1]		Foreign		
				Among all graduate students	Among U.S. citizens	Males	Females	From developing countries
Total	7,317	7,484	33	9	13	25	9	26
Control								
Public	6,878	7,042	33	8	13	26	9	26
Land-grant[2]	6,142	6,283	32	8	13	27	9	27
Private	439	442	43	14	18	13	9	15
Research size[3]								
Top 20	1,326	1,368	37	8	10	17	7	18
Not in top 20	5,991	6,116	32	9	14	26	10	28
Plant biology faculty								
1 - 5	228	221	40	13	18	16	13	25
6 - 25	1,208	1,224	41	11	14	14	6	15
26 or more	5,881	6,039	32	8	13	27	10	28
Region								
Northeast	716	735	43	5	8	17	11	14
Central	2,120	2,175	32	6	10	23	9	25
Southeast	2,455	2,530	31	9	15	28	10	29
West	2,026	2,044	34	11	17	25	8	27

[1]Data on minorities were collected only for graduate students who were U.S. citizens.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-10. Full-time graduate students in plant biology programs, and the percentage female and racial/ethnic minorities, academic year 1982-83: United States

Institutional characteristic	Total full-time graduate students		Percentage of full-time graduate students in 1982-83 who were				
					Foreign		
	1982-83	1983-84 (estimate)	Female	Racial/ ethnic minorities[1] among U.S. citizens)	Males	Females	From developing countries
Total	8,023	8,040	31	7	16	4	16
Control							
Public	7,648	7,670	31	6	16	4	16
Land-grant	6,442	6,500	29	7	18	4	17
Private	375	370	33	16	13	5	13
Research size[2]							
Top 20	1,768	1,750	32	5	11	3	8
Not in top 20	6,255	6,290	31	8	17	4	18

[1]Includes only racial/ethnic minorities who are also U.S. citizens and non-U.S. citizens with permanent visas. Base is total full-time graduate students in plant biology programs who are racial/ethnic minorities, not total full-time graduate students in plant biology.

[2]Based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

SOURCE: Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Tables 3, 4 and 5, pp. 16-19.

Table A-11. Number of Ph.D. recipients in plant biology, and the percentage female and racial/ethnic minorities by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Total Ph.D. recipients		Percentage of Ph.D. recipients in 1988-89	
	1988-89	1989-90 (estimate)	Female	Minority racial/ethnic group[1]
Total	724	859	27	10
Control				
Public	653	780	26	8
Land-grant[2]	595	695	26	8
Private	71	79	32	28
Research size[3]				
Top 20	142	172	34	15
Not in top 20	582	687	25	8
Plant biology faculty				
1 - 5	33	43	33	15
6 - 25	109	144	32	21
26 or more	582	672	26	7
Region				
Northeast	85	98	33	6
Central	229	263	28	9
Southeast	228	287	23	7
West	182	211	29	17

[1]This column includes only minority members who were also U.S. citizens. No data were collected on the number of non-U.S. citizens among Ph.D. recipients.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-12. Ph.D. recipients in plant biology programs, and the percentage female and racial/ethnic minorities, academic year 1982-83: United States

Institutional characteristic	Total Ph.D. recipients		Percentage of Ph.D. recipients in 1982-83	
	1982-83	1983-84 (estimate)	Female	Racial/ethnic minorities[1]
Total	925	1,050	21	5
Control				
Public	868	970	20	5
Land-grant	740	810	19	6
Private	57	80	32	2
Research size[2]				
Top 20	291	290	22	3
Not in top 20	634	760	21	6

[1]This column includes only minority members who were also U.S. citizens. No data were collected on the number of non-U.S. citizens among Ph.D. recipients.

[2]Based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

SOURCE: Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Tables 3 and 4, pp. 16-17.

Table A-13. Number of departmental representatives who ranked various disciplines as being among the top three in training graduate students, postdoctoral research and training, and faculty research at their institutions, by discipline, academic year 1988-89: United States

Discipline	Graduate student training[1]			Postdoctoral research and training[2]			Faculty research[3]		
	Most students	Second most students	Third most students	Most post-doctorates	Second most post-doctorates	Third most post-doctorates	Most faculty	Second most faculty	Third most faculty
Total	153	149	135	113	90	77	152	149	134
Agronomy/soil science	16	6	9	7	4	3	12	5	6
Anatomy/ morphology	1	1	2	0	1	0	2	2	3
Biochemistry	8	14	7	16	11	4	11	13	5
Cell biology	5	12	5	6	5	6	11	7	9
Developmental biology	4	7	6	2	6	1	5	6	7
Ecology	30	14	22	10	9	5	21	20	20
Evolution	1	2	3	0	2	1	2	4	1
Forestry/natural resources	4	3	1	0	3	2	4	5	3
Genetics	9	10	12	4	10	8	5	11	10
Horticulture/crop science	8	9	7	1	3	2	8	5	3
Microbiology	3	4	3	3	3	2	2	6	2
Molecular biology	29	12	20	33	12	10	24	14	22
Plant pathology	2	11	4	6	4	5	6	8	7
Plant physiology	16	30	19	18	10	13	21	29	22
Systematics	10	14	9	2	5	11	13	12	9
Weed science	2	0	3	0	1	2	0	2	3
Other	5	0	3	5	1	2	5	0	2

[1]Ranking is based on the greatest number of graduate students in an institution's plant biology program.

[2]Ranking is based on the greatest number of postdoctorates in an institution's plant biology program.

[3]Ranking is based on the greatest number of faculty in an institution's plant biology program.

SOURCE: Higher Education Surveys, Plant Biology and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-14. Number of full-time vacancies in plant biology in fall 1988 for which institutions were actively recruiting, the disciplines in which the need was greatest, and the source of that need, by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Number of full-time vacancies		Disciplines with greatest need to fill vacancies[1] (percent of institutions)			Reason for greatest need (percent of institutions with vacancies)			
	Total	Mean per institution[2]	Molecular biology	Plant physiology	Other[3]	Increased graduate enrollments	Faculty retirements/ departures	Research opportunities	Other
Total	276	3.4	33	11	56	5	42	48	5
Control									
Public	236	3.3	34	11	55	4	43	50	3
Land-grant[4]	209	3.4	35	11	53	2	46	49	3
Private	40	3.6	27	9	64	9	36	36	18
Research size[5]									
Top 20	56	3.5	44	13	44	7	40	53	0
Not in top 20	220	3.3	30	11	59	5	42	47	6
Plant biology faculty									
1 - 5	6	1.2	40	20	40	0	60	40	0
6 - 25	90	2.6	40	11	49	11	26	51	11
26 or more	180	4.3	26	10	64	0	54	46	0
Region									
Northeast	38	3.8	20	10	70	10	50	40	0
Central	78	3.0	27	19	54	0	52	44	4
Southeast	102	4.4	39	4	57	4	35	57	4
West	58	2.5	39	9	52	9	35	48	9

[1]Each institution with at least one vacancy was asked to state the single discipline with the greatest need to fill vacancies at the institution. Institutions with no vacancies are not included.

[2]Based on institutions with vacancies.

[3]Disciplines other than molecular biology and plant physiology that were included among the responses were agronomy/soil science, anatomy/morphology, biochemistry, cell biology, developmental biology, ecology, evolution, genetics, horticultural/crop science, microbiology, plant pathology, systematics, and other responses.

[4]One land-grant institution is a private institution that has been granted the use of some public land.

[5]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

NOTE: Percentages may not add to 100 due to rounding.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-15. Number of times program representatives listed disciplines among the top two in which their institution was experiencing a "surplus" or "shortage" of positions, by employment category and discipline, academic year 1988-89: United States

Discipline	Employment category											
	Postdoctoral training positions		Permanent doctoral research associate positions		Tenure-track faculty positions		Industrial positions		Federal/state government positions		Nonprofit research institutions	
	Surplus	Shortage	Surplus	Shortage	Surplus	Shortage	Surplus	Shortage	Surplus	Shortage	Surplus	Shortage
All disciplines	0	4	0	6	0	5	0	4	0	3	0	3
Agronomy/soil science	5	8	3	8	3	6	5	9	4	5	1	5
Anatomy/ morphology	4	20	3	15	3	20	3	15	4	10	4	9
Biochemistry	26	9	14	16	20	11	21	11	12	10	14	11
Cell biology	12	10	9	9	10	9	9	4	5	3	7	6
Developmental biology	3	9	4	9	4	11	5	4	3	8	4	5
Ecology	9	28	10	24	9	27	6	15	8	19	7	14
Evolution	2	9	2	10	2	11	1	9	3	10	3	11
Forestry/natural resources	0	2	1	1	0	0	3	3	8	5	1	0
Genetics	9	5	7	1	7	2	5	4	7	1	5	1
Horticulture/crop science	2	6	3	7	6	6	9	8	5	6	3	4
Microbiology	6	7	4	5	6	5	7	7	4	4	5	5
Molecular biology	52	25	45	19	47	26	43	25	30	20	35	20
Plant pathology	6	4	6	4	6	7	3	6	5	6	5	4
Plant physiology	15	10	9	13	9	19	7	14	8	14	5	11
Systematics	4	30	5	25	5	30	3	22	2	21	4	21
Weed science	1	1	0	1	1	5	4	2	1	2	0	1
Other	3	4	2	4	2	4	2	3	3	4	0	2

NOTE: Program representatives were asked to state the top two disciplines experiencing a surplus (or shortage) for each employment category. Some, rather than stating the top two, replied that "all" disciplines were experiencing a surplus (or shortage). These responses are listed separately in the first line of this table.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-16. Total dollar amount of outside financial support for plant biology research reported by program representatives, by source of funds and institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Total (in thousands)	Source of funds (percent)						
		Hatch funds[1]		Other federal government	Other state government	Industry	Other private support	Foreign sources
		Federal government	State government					
Total	$242,488.8	8	23	41	11	9	8	0
Control								
Public	224,457.6	9	25	38	12	9	8	0
Land-grant[2]	212,389.3	9	24	39	12	9	7	0
Private	18,031.2	2	0	73	4	11	9	2
Research size[3]								
Top 20	76,256.8	7	47	30	3	6	7	0
Not in top 20	166,232.0	9	11	45	15	10	8	1
Plant biology faculty								
1 - 5	8,091.7	4	0	64	5	15	8	3
6 - 25	33,433.1	7	5	70	4	6	8	1
26 or more	200,964.1	9	27	35	12	9	8	0
Region								
Northeast	15,211.6	12	4	59	9	10	6	0
Central	49,985.6	11	14	41	9	15	10	1
Southeast	80,271.1	8	13	40	20	9	9	1
West	97,020.5	7	38	38	6	5	6	0

[1]The Hatch Act of 1887 established agricultural experiment stations to conduct agricultural research.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

NOTE: Five institutions were not able to provide data on funding for plant biology, and other institutions were unable to identify all plant biology funding. Thus, these totals are underestimates of the total outside funding for plant biology research. Also, for roughly 4 percent of the funds, institutions were only able to provide totals, not the specific source of fundings. Percentages provided here are based on those institutions that could identify the source of funds. Percentages may not add to 100 due to rounding.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-17. The number of full-time graduate students in plant biology and their major source of financial support, by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Total number of students	Graduate students' major sources of support (percent of students)[1]							
		Federal fellowship	Federal research grant	State government	Foreign government	Institutional support	Industry	Personal funds	Other
Total	7,317	4	21	15	10	28	5	11	6
Control									
Public	6,878	3	21	15	10	27	6	11	6
Land-grant[2]	6,142	4	21	16	11	26	6	11	6
Private	439	12	19	2	5	49	3	7	4
Research size[3]									
Top 20	1,326	7	24	10	7	29	5	12	6
Not in top 20	5,991	3	20	16	10	28	5	11	6
Plant biology faculty									
1 - 5	228	10	14	7	3	45	4	11	6
6 - 25	1,208	6	17	5	3	54	3	10	2
26 or more	5,881	3	22	17	12	22	6	11	7
Region									
Northeast	716	5	31	7	4	37	3	11	3
Central	2,120	3	23	13	11	26	9	10	6
Southeast	2,455	3	17	17	8	31	5	11	8
West	2,026	5	20	17	13	24	4	13	5

[1]Percentages are based on the 98 percent of students for whom the major source of financial support could be identified.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

NOTE: Percentages may not add to 100 due to rounding.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

Table A-18. Full-time graduate students in plant biology programs by major source of support, academic year 1982-83: United States

Institutional characteristic	Total number of students	Source of funds (percent)							
		Hatch funds		State government	Foreign government	Institutional support	Industry	Personal funds	Other
		Federal fellowship	Federal research grant						
Total	8,023	3	20	12	11	30	7	15	4
Control									
Public	7,648	3	20	12	11	29	7	15	4
Land-grant	6,442	3	20	13	12	26	8	15	4
Private	375	13	20	1	3	52	2	8	2
Research size*									
Top 20	1,768	6	27	7	7	29	9	11	5
Not in top 20	6,255	3	18	13	12	30	6	16	3

*Based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

NOTE: Percents may not total to 100 due to rounding.

SOURCE: Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 10, pp. 26-27.

Table A-19. The number of postdoctoral fellows/associates in plant biology, and their major source of financial support, by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Total number of students	Postdoctorates' major sources of support (percent of postdoctorates)[1]							
		Federal fellowship	Federal research grant	State government	Foreign government	Institutional support	Industry	Personal funds	Other
Total	1,120	7	52	12	6	6	7	3	6
Control									
Public	964	6	55	11	6	6	7	3	5
Land-grant[2]	891	5	55	12	6	6	7	4	5
Private	156	17	36	14	10	6	8	0	9
Research size[3]									
Top 20	333	9	46	15	9	6	5	4	6
Not in top 20	787	6	55	10	6	6	8	3	6
Plant biology faculty									
1 - 5	67	21	33	10	4	3	13	0	15
6 - 25	277	13	54	9	12	6	4	0	2
26 or more	776	4	53	13	5	7	8	4	6
Region									
Northeast	108	17	44	8	6	5	8	7	5
Central	330	6	55	6	6	9	10	2	6
Southeast	279	4	53	13	5	6	9	1	10
West	403	7	52	17	8	5	4	4	4

[1]Percentages are based on the 95 percent of postdoctorates for whom the major source of financial support could be identified.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

NOTE: Percentages may not add to 100 due to rounding.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

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Table A-20. Postdoctoral fellows in plant biology programs by major source of support, academic year 1982-83: United States

Institutional characteristic	Total number of students	Source of funds (percent)							
		Hatch funds		State government	Foreign government	Institutional support	Industry	Personal funds	Other
		Federal fellowship	Federal research grant						
Total	1,009	6	54	7	11	8	8	1	6
Control									
Public	871	4	56	8	11	7	9	1	5
Land-grant	731	3	54	9	11	7	9	1	6
Private	138	22	39	1	10	11	7	2	9
Research size*									
Top 20	398	11	51	5	9	6	9	1	9
Not in top 20	611	3	56	8	12	8	8	1	4

*Based on federally financed R&D expenditures in the life sciences for fiscal year 1982.

NOTE: Percents may not total to 100 due to rounding.

SOURCE: Plant Biology Personnel and Training at Doctorate-Granting Institutions, Higher Education Panel Report No. 62, November 1984, American Council on Education, Table 10, pp. 26-27.

Table A-21. The percentage of program representatives reporting that various factors limit progress in plant biology at their institutions, and the mean rank of each factor, by institutional characteristic, academic year 1988-89: United States

Institutional characteristic	Factors limiting progress[1]													
	Intellectual isolation		Insufficient financial support for research		Poor quality of graduate and undergraduate students		Lack of nationally competitive faculty		Inadequate equipment/ instrumentation		Insufficient financial support for graduate students		Lack of university and department commitment	
	Percent	Mean rank	Percent	Mean rank	Percent	Mean rank	Percent	Mean rank	Percent	Mean rank	Percent	Mean rank	Percent	Mean rank
Total	45	4.4	86	1.9	53	3.8	41	4.3	65	3.4	83	2.5	57	3.5
Control														
Public	49	4.4	90	1.9	59	3.8	47	4.3	73	3.4	88	2.6	58	3.8
Land-grant[2]	48	4.4	91	1.9	64	3.8	51	4.5	74	3.4	89	2.6	53	4.0
Private	37	4.3	76	2.0	37	3.7	24	4.4	41	3.5	68	2.3	56	2.7
Research size[3]														
Top 20	35	4.7	80	1.8	45	3.6	30	3.8	50	3.4	85	2.1	50	4.1
Not in top 20	47	4.4	87	1.9	54	3.8	43	4.4	67	3.4	83	2.6	58	3.5
Plant biology faculty														
1 - 5	49	3.8	77	1.9	45	4.4	38	4.4	55	3.3	70	2.9	72	3.0
6 - 25	40	4.1	87	2.0	52	3.5	33	3.7	57	3.8	82	2.4	53	3.0
26 or more	49	5.3	96	1.9	64	3.7	53	4.8	85	3.2	98	2.4	47	5.0
Region														
Northeast	32	4.5	82	1.9	50	3.8	26	4.7	53	3.6	79	2.6	59	2.8
Central	56	4.8	86	1.9	58	3.8	53	4.2	72	3.4	79	3.0	70	3.9
Southeast	47	3.7	89	1.9	53	3.9	44	4.6	67	3.5	82	2.5	56	3.5
West	44	4.9	88	1.9	50	3.6	34	4.0	66	3.0	94	2.1	41	3.9

[1]Mean ranks are based on a system where "1" indicates the area that limits progress the most, "2" the area that limits progress the second most, etc.

[2]One land-grant institution is a private institution that has been granted the use of some public land.

[3]Based on federally financed R&D expenditures in the life sciences for fiscal year 1988, published in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990). See Appendix B for a list of institutions.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989).

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APPENDIX B

TECHNICAL NOTES

Higher Education Surveys (HES)

The Higher Education Surveys (HES) system was established to conduct brief surveys of higher education institutions on topics of interest to Federal policymakers and the education community. The system is sponsored by the National Science Foundation, the U.S. Department of Education, and the National Endowment for the Humanities.

HES questionnaires typically request a limited amount of readily accessible data from a subsample of institutions in the HES panel, a stratified, nationally representative sample of 1,093 colleges and universities in the United States. Each institution in the panel has identified a HES campus representative, who serves as survey coordinator. The campus representative facilitates data collection by identifying the appropriate respondent for each survey and distributing the questionnaire to that person.

Survey Methodology

This mail survey was conducted at the request of the Directorate for Biological, Behavioral, and Social Sciences of the National Science Foundation to provide reliable national estimates on plant biology training and personnel at higher education institutions.

The sample for this survey consisted of all doctorate-granting institutions plus those institutions that could be identified as granting doctoral degrees in plant biology. Doctorate-granting institutions were defined using the U.S. Department of Education's Higher Education General Information Surveys (HEGIS) classifications: namely, schools characterized by a significant level and breadth of activity in and commitment to doctoral-level education as measured by the number of doctorate recipients and the diversity in doctoral-level program offerings. Some institutions meeting this definition did not offer doctorates specifically in plant biology (though they did offer graduate instruction in plant biology), but were included as doctorate-granting institutions. To identify other institutions not meeting the HEGIS definition but that did offer doctorates in plant biology, the list was augmented based on the National Science Foundation's Fall 1987 Survey of Graduate Science and Engineering Students and Postdoctorates. Following these criteria, a total of 198 eligible institutions were identified. These institutions should comprise the entire universe of United States institutions offering doctorates in plant biology, as well as some doctorate-granting institutions offering graduate instruction (but not doctorates) in plant biology.

The questionnaire was mailed on April 28, 1989 to doctorate-granting institutions and on May 2, 1989 to institutions granting doctorates in plant biology. Plant biology personnel and programs may be dispersed across many separate departments, and there often is no single location capable of providing comprehensive information for the entire institution. Therefore, each institution was asked to designate a coordinator knowledgeable in plant biology who would coordinate the collection of data from all departments with plant biology faculty. In a few cases, no institutional

coordinator could be named, and separate questionnaires were completed by every department identified as having plant biology programs. Those separate questionnaires were aggregated by Westat to provide institution-wide totals. Some questions could not be aggregated because they asked for perceptions rather than numeric data (e.g., department representatives' perceptions of the employment market in plant biology); in this case, the perceptions of the representative of the department with the greatest number of plant biology faculty was used if no institutional coordinator were available to provide an institution-wide judgment.

Telephone followup for nonresponse was begun on May 22. Completed questionnaires were examined for internal inconsistencies and missing data. Telephone followup was performed to verify the information in question. By July 21, responses had been received by 96 percent of the institutions. However, because some key institutions known to have large programs in plant biology had not yet responded, data collection was extended to allow as accurate of a picture of plant biology as possible. Additional follow-up activities were done and data collection ended on December 12, 1989.

The overall response rate was 99 percent, based on 197 responses from 198 eligible institutions. From the questionnaires, 43 institutions were identified as not offering graduate education in plant biology, and were excluded from the analysis. The one institution that did not complete the questionnaire was identified as having a small plant biology program. Because of the small size of the nonresponding institution's plant biology program, its exclusion has little effect on the national totals presented in this report. Therefore, no weighting was performed to correct for questionnaire nonresponse.

The item response rate was 97 percent or higher for all but two questions on the questionnaire (Appendix Table B-1). The exceptions were the amount of outside support for plant biology research (97 percent were able to provide the total amount, but only 95 percent indicated the support levels for each component), and the description of the current market for employment in plant biology (with item response rates of 78 percent or higher). Specific notes on the importance of item nonresponse for these last two questions are included within the text. For all other items, item nonresponse was minimal, and statistics presented in this report may be interpreted as representing all doctoral training in plant biology.

Survey estimates are also subject to errors of reporting and errors made in the collection of the data. These errors, called nonsampling errors, can sometimes bias the data. While general sampling theory

Table B-1. Response rate for each item on the plant biology questionnaire: United States

Question number	Description	Response rate
1	Administrative unit that is primary focus for plant biology training	100
2	Names of departments*	100
	Total number of faculty per department*	100
	Faculty training graduate students, per department*	100
	Faculty with bachelor's degrees from foreign institutions	98
3	Faculty with bachelor's degrees from foreign institutions teaching undergraduates	99
4	Number of graduate students, Ph.D. recipients, postdoctorates, and faculty	
	All but 1989-90 estimate for graduate students	100
	1989-90 estimate for graduate students	99
5	Number of foreign graduate students and postdoctorates	100
6	Institution's three major disciplines in plant biology	
	Graduate student training	100
	Postdoctoral research and training	100
	Faculty research	99
7	Faculty vacancies	
	Number of vacancies	100
	Discipline with greatest need	100
	Reason for greatest need	99
8	Current market for employment	
	Postdoctoral training positions	86
	Permanent doctoral research associate positions	86
	Tenure-track faculty positions	86
	Industrial positions	80
	Federal/state government positions	80
	Nonprofit research institutes	78
9	Factors limiting progress in plant biology	100
10	Major source of support	
	Graduate students	99
	Postdoctorates	97
11	Amount of outside support for plant biology research	
	Total	97
	Individual components of outside support	95
12	Permission to release information	99

*Based on 394 total departments listed.

SOURCE: Higher Education Surveys, Plant Biology Personnel and Training at Doctorate-Granting Institutions (HES 13), National Science Foundation, 1990 (survey conducted in 1989)

can be used to determine how to estimate the sampling variability of a statistic, nonsampling errors are not easy to measure and usually require that an experiment be conducted as part of the data collection procedures or the use of data external to the study.

Nonsampling errors may include such things as differences in the respondents' interpretation of the meaning of the questions, differences related to the particular time the survey was conducted, or errors in data preparation. During the design of the survey and survey pretest, an effort was made to check for consistency of interpretation of questions and to eliminate ambiguous items. The questionnaire was pretested with respondents like those who completed the survey, and the questionnaire and instructions were extensively reviewed by NSF. Manual and machine editing of the questionnaires was conducted to check the data for accuracy and consistency. Cases with missing or inconsistent items were recontacted by telephone; and these corrected data were keyed with 100 percent verification.

Opinion data may be biased if the respondents wish to promote a particular viewpoint concerning plant biology, or if they are simply mistaken in a systematic manner in their impressions. Also, to limit respondent burden, some questions asked for general impressions instead of requesting specific numerical estimates. However, in many cases the survey responses will represent the only existing data regarding certain issues and, hence, are valuable even given these limitations.

Institutional Relationships

The data in this report are presented as "total" figures, which represent all kinds of institutions grouped together, and for institutions broken down by institutional control and size. These classifications are:

- Institutional control
  - Public
  - Land-grant institutions (includes one private institution that was granted use of some public land)
  - Private
- Research size
  - Top 20 in federally financed R&D expenditures in the life sciences in fiscal year 1988
  - Not in top 20

- Number of full-time plant biology faculty
  - 1 to 5 faculty
  - 6 to 25 faculty
  - 26 or more faculty

These school characteristics are related to each other:

- Among the 20 largest institutions in the life sciences, 11 are public.
- Among the institutions with 26 or more plant biology faculty, 98 percent are public.
- Among the 20 largest institutions in the life sciences, 12 have from 6 to 25 faculty in plant biology.
- Among the institutions with 26 or more plant biology faculty, 11 percent are among the 20 largest institutions in the life sciences.
- Among institutions with 5 or fewer plant biology faculty, 51 percent are public.
- Among the 20 largest institutions in the life sciences, 12 are land-grant institutions.
- Among institutions with 26 or more plant biology faculty, 91 percent are land-grant institutions.

The measure of the 20 largest institutions was chosen specifically to determine the relationship between the size of plant biology programs and federal financing of the life sciences. It should not be considered as a general measure of size. Beyond the $4.3 billion dollars in federally financed R&D expenditures in the life sciences in 1988, there was an additional $2.9 in nonfederal R&D expenditures.* Further, expenditures for the life sciences included the medical sciences (47 percent of all R&D expenditures in 1988), the biological sciences (33 percent), the agricultural sciences (28 percent), and other life sciences (4 percent), and thus encompassed far more than plant biology. Of the 20 largest

*R&D expenditures in the life sciences may be found in **Academic Science/Engineering R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326, Detailed Statistical Tables (Washington, D.C., 1990).

institutions in federally financed R&D expenditures in the life sciences, only 14 had graduate programs in plant biology; thus, to select 20 institutions for comparison purposes in this report, it was necessary to select from the top 29 institutions in the life sciences (Appendix Table B-2).

Table B-2. Fifty institutions with the largest federally financed research and development expenditures in the life sciences: United States, 1988 fiscal year

Rank		Institution	Rank		Institution
1	*	University of California-San Francisco	26		University of California-Davis
2		Johns Hopkins University	27		University of Iowa
3		Yale University	28	*	UT SW Medical Center-Dallas
4		Stanford University	29		University of Colorado
5		University of Washington	30		SUNY at Buffalo
6		University of California-Los Angeles	31		Boston University
7		University of Michigan	32		University of California-Berkeley
8		University of Minnesota	33	*	Emory University
9		Harvard University	34		Case Western Reserve University
10		University of Wisconsin-Madison	35		University of Utah
11		University of Pennsylvania	36		Vanderbilt University
12	*	Columbia University Main Division	37	*	Tufts University
13		Washington University	38		University of Miami
14		University of California-San Diego	39		University of Arizona
15		Cornell University	40		Ohio State University
16		Duke University	41		Rockefeller University
17		University of North Carolina-Chapel Hill	42		University of Florida
18	*	Baylor College of Medicine	43	*	University of MD Baltimore Professional School
19	*	University of Alabama-Birmingham	44	*	CUNY Mt. Sinai School of Medicine
20	*	University of Rochester	45		Northwestern University
21	*	Yeshiva University	46		University of Georgia
22	*	University of Pittsburgh	47		Pennsylvania State University
23		New York University	48		University of Connecticut
24	*	University of Southern California	49		Virginia Commonwealth University
25		University of Chicago	50	*	Massachusetts Institute of Technology

*Does not have doctoral program in plant biology.

SOURCE: **Academic Science/Engineering: R&D Funds -- Fiscal Year 1988**, National Science Foundation, NSF 89-326 (Washington, D.C., 1990)

APPENDIX C

SURVEY QUESTIONNAIRE--1989

OMB # 3145-0009
Exp. 1/31/90

Higher Education Surveys

SURVEY #13
PLANT BIOLOGY TRAINING AND PERSONNEL

April 1989

Dear Colleague:

I am writing on behalf of the National Science Foundation to request your participation in our Higher Education Survey (HES) on *Plant Biology Training and Personnel.*

In October 1983 a survey on plant biology was sent to 210 doctorate-granting institutions, and the resulting report, *Plant Biology Personnel and Training at Doctorate-granting Institutions*, was instrumental in providing data and helping to support new funding programs in plant science at NSF, the U.S. Department of Energy, and the U.S. Department of Agriculture. Now we need to update this information to continue our planning for federal support efforts.

Because of the survey's nature, it is essential that someone familiar with plant biology coordinate the data collection at your school. The staff of the American Society of Plant Physiologists (ASPP) suggested that you are well qualified for this task. Please be aware, though, that you will probably need to work with plant biologists in other departments to produce the institution-wide data that are required.

Your institution has also been surveyed recently on systematic biology, and we apologize for timing two such surveys so closely. However, we hope you understand the importance of this information for establishing federal funding, as well as for use by universities, industry, and professional societies. The survey has been strongly endorsed by Mel Josephs, Executive Director of the ASPP, and his letter is included with this package.

The survey is being conducted for us by HES. If you have any questions about the survey, please call Bradford Chaney of Westat (800-937-8281).

Thank you for your assistance. We believe the goal will be worth our combined efforts.

Sincerely,

Mary E. Clutter

Mary E. Clutter, Assistant Director
Biological, Behavioral, and Social Sciences
National Science Foundation

Sponsored by the National Science Foundation, the National Endowment for the Humanities, and the Department of Education

1. Please indicate the major administrative unit at your institution that is the primary focus for training graduate students in plant biology. (Check only one.)

- ☐ Division/College of Arts and Sciences
- ☐ School/College/Division of Agriculture/Forestry/Natural Resources
- ☐ Other (specify)_____
- ☐ Not currently training graduate students in plant biology (fill out institutional information on last page and return questionnaire)

Please complete the remainder of this questionnaire with reference to ALL graduate plant biology personnel and training at your institution.

2. Please list the department(s) involved in training graduate students in plant biology in 1988-89 at your institution. For each department, indicate (1) the total number of *plant biology* faculty, (2) the number of those faculty *engaged in training graduate students* in 1988-89; and (3) the number of your institution's plant biology faculty who obtained their bachelor's degree in foreign countries. Count faculty members only once, i.e., with their major department affiliation. Consider faculty as full-time if they are employed full-time at your institution (i.e., not only if they are full-time in plant biology).

	Number of full-time plant biology faculty		
Department	Total	Faculty training graduate students	With bachelor's degrees from foreign institutions
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

3. Of all of your institution's plant biology faculty with bachelor's degrees from foreign institutions, how many are teaching undergraduates?

_____

4. Please indicate the number of full-time graduate students, Ph.D. recipients, postdoctoral fellows/associates, and faculty in your plant biology program(s). For 1988-89, please provide the total number, the number of males and females, and the number who are members of minority racial/ethnic groups (see definition in box below); for 1989-90, show only estimated totals. Note that the 1988-89 totals for graduate students and postdoctorates should agree with corresponding totals in question 10. In the last row, include all full-time faculty, not just those training students. **When counting those in minority racial/ethnic groups, include only native-born U.S. citizens.**

	1988-89				
	Total	Males	Females	Minority racial/ ethnic groups	1989-90 Total (estimate)
a. Full-time graduate students	_____*	_____	_____	_____	_____
b. Ph.D. recipients (degrees awarded)	_____	_____	_____	_____	_____
c. Postdoctoral fellows/associates	_____*	_____	_____	_____	_____
d. Full-time faculty	_____	_____	_____	_____	_____

*These figures should agree with the corresponding totals in question 10.

MINORITY RACIAL/ETHNIC GROUPS
American Indian/Alaskan Native, Asian or Pacific Islander, Black, or Hispanic

5. How many *foreign* full-time graduate students and postdoctoral fellows/associates were in your 1988-89 plant biology program(s)? Please show men and women separately. Also show the total number of these individuals (men plus women) who were from *Developing Countries* (see definition in box below). **Count as foreign students and postdoctorates those non-U.S. citizens on temporary visas.**

	Number of men	Number of women	Number from developing countries
a. Foreign graduate students	_____	_____	_____
b. Foreign postdoctorates	_____	_____	_____

DEVELOPING COUNTRIES BY REGION
Countries in Latin America and the Caribbean
Countries in the Far East, excluding Japan
Countries in South Asia, including India, Afghanistan, Bangladesh, Pakistan, and Sri Lanka
Countries in Africa, excluding South Africa
Countries in the Near and Middle East, including Turkey, Iran, Saudi Arabia, Lebanon, Jordan, Egypt, and Syria, but excluding Israel

DISCIPLINE CODES

A. Agronomy/soil science	G. Evolution	M. Plant pathology
B. Anatomy/morphology	H. Forestry/natural resources	N. Plant physiology
C. Biochemistry	I. Genetics	O. Systematics
D. Cell biology	J. Horticulture/crop science	P. Weed science
E. Developmental biology	K. Microbiology	Q. Other (specify)
F. Ecology	L. Molecular biology	_____

6. Indicate *in rank order* the three major disciplines in your plant biology program(s) that have the greatest number of (a) graduate students, (b) postdoctorates, and (c) faculty. Select a code from the list above and place it in the column that represents its appropriate rank.

Type of training/research	Highest	2nd Highest	3rd Highest
a. Graduate student training	_____	_____	_____
b. Postdoctoral research and training	_____	_____	_____
c. Faculty research	_____	_____	_____

7. Faculty vacancies in plant biology.

   a. For how many full-time faculty vacancies (budgeted positions) was your institution actively recruiting in fall of 1988 in all of your plant biology programs? Include only those positions specifically dedicated to plant biology (e.g., if you were filling a position in molecular biology, count that position only if you specifically sought a molecular biologist who was also a plant biologist).

   _____ Full-time vacancies

   b. For your institution, in which discipline is the need to fill vacancies greatest? Use a discipline code from the box above.

   _____ Discipline with greatest need

   To what do you attribute this need? Check the *single most important*.

   ☐ (1) Increased graduate enrollments

   ☐ (2) Faculty retirements/departures

   ☐ (3) Research opportunities

   ☐ (4) Other (specify)_____

   _____

8. How would you characterize the "current market" for employment in plant biology? (Please answer for your entire institution, not just for one department.)

For each of the employment categories below, enter the code for the two disciplines most experiencing a surplus of positions, and the two most experiencing a shortage. If there are no disciplines experiencing a surplus (or shortage) for an employment category, please write "None." Use discipline codes from question 6. A surplus of positions means there are more positions available than trained people to fill them. A shortage of positions means that there are not enough positions for all the qualified people who are applying for them.

Employment category	Discipline(s) with surplus of positions	Discipline(s) with shortage of positions
a. Postdoctoral training positions	_____	_____
b. Permanent doctoral research associate positions	_____	_____
c. Tenure-track faculty positions	_____	_____
d. Industrial positions	_____	_____
e. Federal/state government positions	_____	_____
f. Nonprofit research institutes	_____	_____

9. Please check those factors that limit progress in plant biology in your institution, and rank them in order of importance. Write "1" for the area that limits progress the most, "2" for the area that limits progress the second most, etc. Please rank all items checked.

☐ Check here if there are no major problems limiting progress, and skip to question 10.

	Limits progress	Rank
a. Intellectual isolation	☐	_____
b. Insufficient financial support for research	☐	_____
c. Poor quality of graduate and undergraduate students	☐	_____
d. Lack of nationally competitive faculty	☐	_____
e. Inadequate equipment/instrumentation	☐	_____
f. Insufficient financial support for graduate students	☐	_____
g. Lack of university and department commitment to plant biology	☐	_____
h. Other (specify)_____	☐	_____

10. List the number of full-time graduate sudents and postdoctoral fellows/associates in your plant biology program(s) by their *major* source of support. Count each individual only once. The totals should agree with the corresponding totals in question 4.

Source	Graduate students	Post-doctorates
a. Federal fellowship	_____	_____
b. Federal research grant	_____	_____
c. State government	_____	_____
d. Foreign government	_____	_____
e. Institutional support	_____	_____
f. Industry	_____	_____
g. Other non-industry, non-personal support (foundations, associations, etc.)	_____	_____
h. Personal funds	_____	_____
i. TOTAL*	_____	_____

*The total should agree with corresponding totals in question 3.

11. Indicate the amount of support for plant biology *research* that your institution received from the outside in FY 1988-89 from each of the sources listed below. If exact figures are not yet available, please give estimates. Please include only funds given to faculty members to support research, not funds used for faculty salaries. If a multi-year award was received in FY 1988-89, state only that portion that supported research conducted during the year.

Source	Amount
a. Hatch funds	
Federal government	$ _____
State government	$ _____
b. Other Federal government	$ _____
c. Other State government	$ _____
d. Industry	$ _____
e. Other private support (foundations, associations, etc.)	$ _____
f. Foreign sources (Please state countries)	$ _____
_____	
_____	
g. TOTAL	$ _____

12. May we have permission to release these data to the National Science Foundation with the institution identifier intact? All information published by NSF will be in aggregate form only.

☐ Yes
☐ No

Please sign_____

Thank you for your assistance.
Please return this form by
May 19 to:

Higher Education Surveys
WESTAT
1650 Research Boulevard
Rockville, MD 20850

Please keep a copy of this survey for your records. Person completing this form:

Name_____

Title_____

Telephone (___)_____

If you have any questions or problems concerning this survey, please call Bradford Chaney at (800) 937-8281 (toll-free).